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THE DECEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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THE SCIENTIFIC MONTHLY

DECEMBER, 1932

THE AGE AND SIZE OF PLANTS

By Professor CHARLES JOSEPH CHAMBERLAIN

UNIVERSITY OF CHICAGO

We are all interested in things which are old and things which are big; and the older and bigger, the more we are interested. As one enters the new Oriental Museum at the University of Chicago, he sees rude, chipped flints, some of them so rude that the layman can scarcely decide whether they have been chipped intentionally or have just happened to be that way; then come others, in which even the layman can see intelligent chipping. In the next cases one sees the immense improvement which marks the Neolithic stage of our ancestry. How old are these things? Archeologists guess that it has been about half a million years since the chipping began. We look down the aisle and see the winged bull from Sargon's palace, and then the lions which adorned the entrance to Nebuchadnezzar's royal halls long before he began to eat grass like an ox. We are human and we have a human interest in such things. But one does not need to be a botanist to have an interest in the age and size of plants.

The age of any individual animal or plant is rather short; and animals do not live nearly so long as plants. A turtle has been known to have reached the age of 370 years; but it could hardly be claimed that they were years of strenuous activity. The higher plants are fixed to one spot for their whole lifetime and often reach a ripe old age.

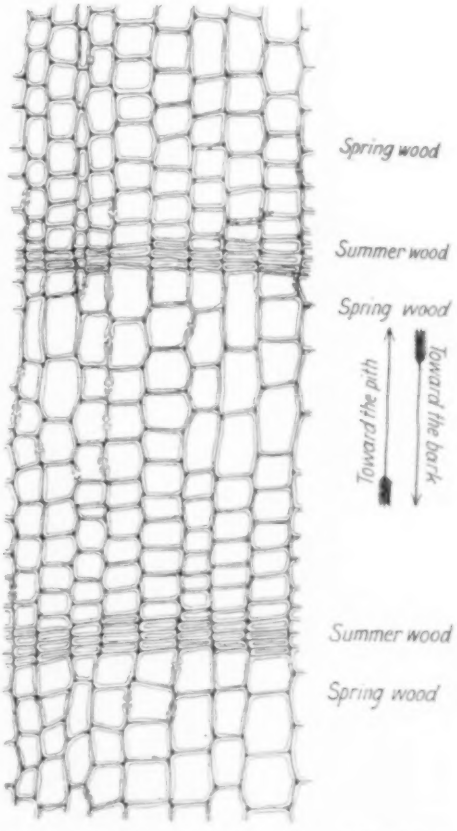

FIG. 1. CROSS-SECTION OF A PIECE OF WOOD OF WHITE PINE

SHOWING ONE COMPLETE ANNUAL RING AND THE SPRING WOOD OF TWO OTHERS. MAGNIFIED 50 DIAMETERS. FROM CHAMBERLAIN'S "ELEMENTS OF PLANT SCIENCE."

FIG. 2. CROSS-SECTION OF TRUNK OF AN 11-YEAR-OLD DOUGLAS FIR
THE DARKER PART OF THE ANNUAL RING IS THE SPRING WOOD AND THE LIGHTER PART IS THE SUMMER WOOD. ONE HALF NATURAL SIZE. FROM CHAMBERLAIN'S "ELEMENTS OF PLANT SCIENCE."

Some plants, like many of our worst weeds, live only one year; some, like the thistle, live two years; and others, like our shrubs and trees, live longer, hundreds or even thousands of years.

The oldest of all living things are trees, and among the trees whose age is most definitely known are the Gymnosperms of our Pacific region. For obvious reasons, they were not included in the original seven wonders of the world; but if travel had not been so restricted in those provincial days, our big trees might well have stood at the head of the list. The age of a tree is determined by counting its annual rings. A plant consists entirely of cells, which, at first, are more or less cubical; but which later assume various forms. In the wood, which constitutes nearly the whole mass of a tree, they are greatly elongated. The cells formed in the spring are large and have comparatively thin walls, while those formed in the summer are small and have thicker walls (Fig. 1). In our latitude there is scarcely any formation of cells in the autumn, and, of course, none in winter. In a cross-section of a piece of wood, as one views it with the naked eye, the small cells of the summer wood look like a dense line. Since the loose, thin-walled cells of the spring wood alternate with the crowded, thick-walled cells of the summer wood, there is a series of annual rings, denser on the outside and softer inside. Hence, to determine the age of a tree, one has only to count the number of annual rings, a simple matter where extensive lumbering is going on. The counting is done on stumps, since counting at the top of a tree would reveal nothing in regard to the age. A tree hundreds of years old would show only one ring at the top.

In a temperate climate, or even in a subtropical or tropical climate with well-marked rainy and dry seasons, the an-

nual rings are distinct and easily counted; but in some of the warmer climates, where the rainy and dry seasons do not alternate so sharply, the zone of wood formed during any year is not so conspicuous. It can be distinguished, but there may be several intermediate rings. While these would not confuse a botanist, they would enable a clever lawyer to confuse a jury in regard to the length of time some piece of land, upon which the trees might be growing, had been in the possession of his client. A comparison of a section of a young Douglas fir (*Pseudotsuga taxifolia*) trunk, growing at Puget Sound Biological Station, with a section of the Australian pine (*Casuarina equisetifolia*), growing on Dry Tortugas, Florida, shows what a difference there can be in annual rings (Figs. 2 and 3). Any one can count the rings in the Douglas fir; but those of the Australian pine are somewhat confusing. Even in a temperate climate, two rings are sometimes formed in one year. When a peach tree flowers in the autumn, the same stimulus which caused the untimely flowering causes a resumption of growth in the wood; but the second ring is weak and does not confuse the botanist in determining the age of the tree.

Thorough work in determining the age and size of trees has been done in our Pacific region. Sudworth's "Trees of the Pacific Slope," published in 1908, presents interesting information along this line; but, since that time, the study

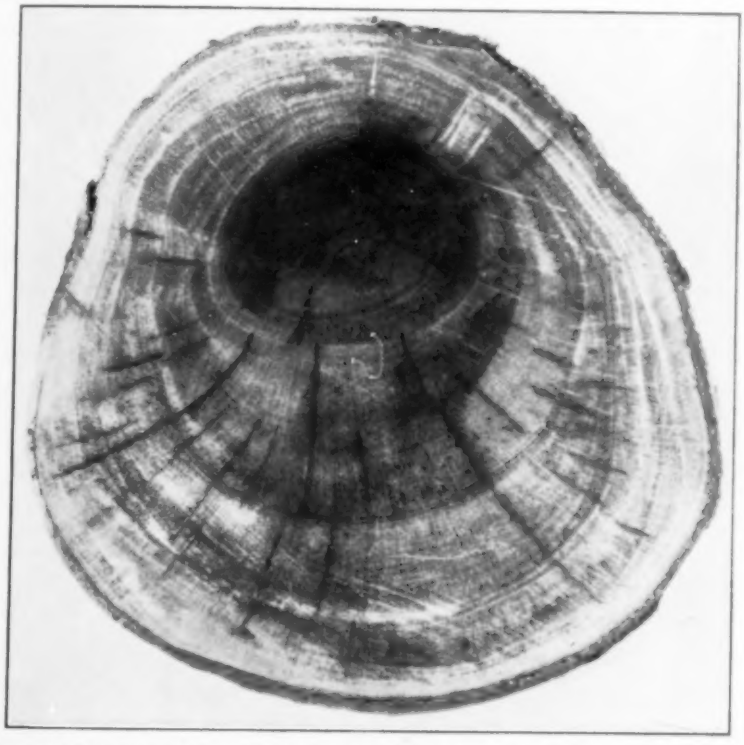

FIG. 3. CROSS-SECTION OF A BRANCH OF AUSTRALIAN PINE (*CASUARINA EQUISETIFOLIA*) GROWING AT DRY TORTUGAS, FLORIDA. THE BRANCH IS 7 YEARS OLD AND 4½ INCHES IN DIAMETER.

of annual rings has progressed beyond the mere counting of their number. In a favorable year, the ring is broader than in an unfavorable year. The seven years of plenty followed by seven years of famine may be recorded in the rings of old trees; and a century of aridity, which may have caused migrations of people, may have left its date in old trees.

In any discussion of the age and size of plants, the trees of our Pacific region should have a prominent place, both on account of their great age and size and on account of the scientific accuracy of the determinations.

Our Western pines are magnificent trees. The Western yellow pine (*Pinus ponderosa*) is often 150 feet high and 350 years old, with occasional specimens 200 feet high, 8 feet in diameter and 500 years old. The sugar pine (*Pinus lambertiana*) is still larger, often 180 feet tall and 7 feet in diameter; and one large tree, near the Calaveras Grove in California, is 11 feet in diameter and more than 200 feet tall. It is probably 600 years old and is the largest known pine in the world.

The Western larch (*Larix occidentalis*) is frequently 180 feet high, 4 feet in diameter and 560 years old, with exceptionally large specimens 700 years old. The Alpine larch (*Larix lyallii*) is comparatively small, only 30 or 40 feet high and 1 or 2 feet in diameter; but 600 years is not an unusual age and some specimens are known to be 700 years old.

The Engelmann spruce (*Picea engelmanni*) is a beautiful, symmetrical tree, often 100 feet tall and 3 feet in diameter; but the rings are very narrow, so that trees less than 2 feet in diameter may show as many as 200 rings.

The Douglas fir is the most important lumber tree of the West. It is often more than 180 feet high and 6 feet in diameter, with occasional trees 200 feet high and 10 feet in diameter. A tree 4 feet in diameter will be about 200 years old; 8 feet in diameter, 400 years old. The Long-Bell Lumber Company is planting millions of trees and expects them to reach, in 35 years, a diameter of 18 inches, the best size from the standpoint of the lumberman.

Forest fires too often prevent trees from reaching the anticipated age. In our Eastern and Middle Western forest regions we can only partly appreciate the havoc wrought by a fire when it gets started in a forest of Douglas fir. Most

FIG. 4. SIGN AT ENTRANCE TO THE LONG-BELL LUMBER COMPANY'S PLANT

FIG. 5. THE BIG TREE OF TULE
FROM CHAMBERLAIN'S "ELEMENTS OF PLANT SCIENCE."

FIG. 6. *SEQUOIA GIGANTEA*

IN THE MARIPOSA GROVE, CALIFORNIA, BURNED COMPLETELY THROUGH. THE MAN, MAJOR LOEHWING, IS MORE THAN 6 FEET TALL.

fires can be charged to tobacco; so the sign at the entrance of the mill of the Long-Bell Lumber Company is not a joke (Fig. 4).

The most famous of all big trees are the Sequoias of California, named after a remarkable Indian chief who invented a phonetic alphabet and taught the braves of his tribe to read and write. There are two species, the redwood (*Sequoia sempervirens*) near the coast, throughout the northern half of the state, with a few trees in Oregon and some as far south as Monterey; and the Big Tree (*Sequoia gigantea*) farther inland, near the central eastern part of the state on the western side of the Sierras. The redwood often grows in dense stands with average large trees 300 feet high, 15 feet in diameter and 1,000 years old. The largest specimens are 350 feet high, 20 feet in diameter and 1,300 years old.

The other species does not grow in dense stands, but in scattered groups, connected by straggling specimens. It is not as tall as the redwood, but is more majestic and is entitled to its name, the Big Tree. The larger trees are from 250 to 280 feet high, with occasional individuals 300 to 330 feet high. In the Calaveras Grove, a house has been built on the top of a stump, the floor, 27 feet in diameter, being the planed-off top of the stump.

Many of the larger trees have their own names, the Illinois Tree, Wisconsin Tree, Vermont Tree, etc., and trees are named after prominent people, the General Grant Tree, the General Sherman Tree; and it is fitting that some of them should be named after botanists, so we have the Asa Gray Tree and the John Torrey Tree.

Recently an attempt was made to find out which might be the biggest of the Big Trees. From the standpoint of the lumberman, the General Sherman is the largest, for it would make 50,000 feet of lumber; the General Grant would make 45,000 feet, and the Hart Tree, 34,000 feet. But the Hart Tree is the tallest, 277 feet high; the General Sherman five feet shorter, and the General Grant ten feet shorter. The General Grant tree has the largest diameter, 33 feet; while the diameter of the General Sherman is 30 feet, and that of the Hart Tree only 26 feet. Which is the biggest? It is like deciding a beauty contest. One girl has the most beautiful hair, another the most beautiful teeth, while another has the most beautiful figure. Which one gets the apple? And which tree gets the medal?

Perhaps none of them. For we have overlooked the Big Tree of Tule, about 250 miles south of the old City of Mexico (Fig. 5). This tree is 50 feet in diameter, not measured at a flaring base, for it is fifty feet in diameter where it begins to branch. It is a Montezuma cypress (*Taxodium mucronatum*), a giant among its kind, like Goliath or the nine and one half foot man of the side show.

How old is the Big Tree of Tule? The most conservative estimate, based upon counting the rings of part of a tree about 4 feet in diameter, would not make the age less than 5,000 years, and it may be much older. Professor W. J. G. Land, who paid particular attention to the wound tissue around the Humboldt inscription and who is a profound student of plant anatomy, thinks that 7,000 years would not be too great an estimate. While the pyramids of Egypt were being built, and later, while Achilles was dragging the dead body of Hector around the walls of Troy, and while Moses was leading the children of Israel out of the wilderness, it was a big tree; when Romulus was killing Remus it had already passed the usual size of its species; when Socrates was drinking the hemlock, it must have been in the legendary stage; and in the days of King

FIG. 7. *DIOON EDULE*

A CYCAD, AT CHAVARRILLO, MEXICO. FIVE FEET TALL AND ABOUT 1,000 YEARS OLD.

FIG. 8. MONTEREY CYPRESS (*CUPRESSUS MACROCARPA*)

Arthur and his table round, pious pilgrims had begun to come and worship this awe-inspiring wonder of nature, as they still come to-day. Even a blasé university professor can not suppress a feeling of awe and veneration as he gazes upon the oldest living thing in the world, a tree which has seen mankind emerge from savagery and climb to its present exalted, semi-savage condition.

The Mexican government should be commended because it will not let John Doe of Kankakee or Sam Jones of Sing Sing carve their names on the bark of the Big Tree of Tule. More than a hundred years ago, before the Mexicans realized that a sacred tree needed any protection, the traveler, Alexander Humboldt, cut through the bark to the wood and carved an inscription, the beginning and end of the lines of which are now overgrown by wound tissue. If he had made accurate measurements and recorded them, instead of merely showing that the great Humboldt had been there, such data might have been a partial excuse for his vandalism.

We should all be grateful to the "Save the Redwoods" league, and to other lovers of nature, for checking the ravages of greedy capitalists who can see only so many feet of lumber and so many dollars in these magnificent trees, which could not be replaced in a thousand years. Many of the Big Trees have tunnels at the base, so that you can drive through and have your picture taken; but these tunnels are not the work of reckless vandals. Accidental fires have burned the holes through and they were merely trimmed into more symmetrical passages (Fig. 6). People have been driving through the "Wawona" tree for more than fifty years, and it seems to do no damage. Some of these burned tunnels are more than fifty feet high, but the trees still stand against the wind and the weather. Fortunately, there are

FIG. 9. AN ARCH OF MONTEREY CYPRESS AT LOS ANGELES, CALIFORNIA

now many parks and reservations where fire and wind are the only enemies with which these splendid trees have to contend.

So far we have considered trees in which great age and great size are associated. No less interesting are plants which reach a great age without a corresponding increase in size. The cycads constitute a small, tropical and subtropical group of seed plants, related to the ferns. Most of them have tuberous, subterranean stems, but many of them have trunks surmounted by a crown of leaves, which makes them look like tree ferns or palms (Fig. 7). As the leaves die, the leaf bases remain on the plant and can be counted. Knowing the average number of leaves in a crown, and also how often a new crown is produced, one can count the number of leaf bases and estimate the age of the plant. If there are 20 leaves in a crown and a new crown is formed every other year, the average is ten leaves a year. If there are 10,000 leaf bases, the age is 1,000 years. The plant shown in Fig. 7 is scarcely more than 5 feet in height, but it has reached the honorable age of 1,000 years; but even a thousand years does not mean that it is dying of old age. When a cycad reaches a height of 4 or 5 feet, the big crown of leaves offers great resistance to wind, and some furious tropical

storm either blows the plant down or makes it lean. The leaning habit is almost universal in the taller cycads. The wood is so heavy that any increase in size accentuates the leaning, and finally the plant falls. But young shoots come up from the ruptured base, so that it is common to find cycads in groups. What age a cycad might reach under ideal conditions is problematical.

With many of the cycads such a slow growth is natural; but many trees grow very slowly when exposed to severe conditions. A western yew, 6 inches in diameter, may be nearly a hundred years old. The Monterey cypress, which is now cultivated the world over in warmer climates, becomes a large, symmetrical tree, but in its native habitat along the wind-swept Monterey Bay it becomes gnarled and twisted, with a flattened top, and trees a foot in diameter may be 50 or 60 years old (Fig. 8). This cypress withstands not only extreme exposure to weather, but can be pruned and trained to an almost unbelievable extent. In California it is popular for hedges, and one often sees an arch made by bending and fastening two young trees together (Fig. 9). By constant pruning and care—or lack of it—these hedges and arches remain small for many years.

The Japanese keep the pines, especially *Pinus thunbergia*, in vases almost indefinitely, preventing any considerable increase in size by taking them out of the vase occasionally and shaking off the soil and repotting. Such trees are handed down from father to son, generation after generation. Some of them, still thriving, are known to be 200 years old.

Practically nothing is known about great age in any of the microscopic plants, but it has been claimed that asexual unicellular organisms are immortal; because reproduction is merely cell division. A cell divides and there are two individuals; each of these divides, and there are four; and so on. Thus, a part of the original cell is still alive, even after millions of years. The claim needs no argument: the truth of it is self-evident. But why should the claim be confined to unicellular organisms? The phenomenon is universal in plants from the lowly unicellular forms up to the highest. There is no death of the entire organism. You have all heard, "Unless the grain of wheat fall into the ground and die, it remains alone; but if it die, it beareth much fruit." Of course, the embryo in the grain of wheat does not die. It was an integral part of its parent, and a part of it will become another embryo; and so there is a continuity of living matter. The same is true of animals, whether they be unicellular organisms or at the human level. So, if there was one original human being, a living part of that original being is a living part of every living being on the earth to-day. The individual dies, but there is continuity of living matter until a race becomes extinct.

In a popular sense, however, we may think of our Western Sequoias and the Big Tree of Tule as the oldest living individuals in the world.

HOW CHANGES ON THE SUN'S SURFACE ARE RECORDED BY THE EARTH'S MAGNETISM

By J. BARTELS

RESEARCH ASSOCIATE, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

THE Sun always appears the same to us, while the Moon's aspect changes from day to day. It has long been known, however, that this difference is merely pictorial. As a matter of fact, the Moon always turns towards us the same rocky face, more or less illuminated by the Sun's rays. The Sun, on the other hand, is a glowing ball of gas, with an ever-changing surface on which dark spots can often be seen, sometimes large enough to be visible to the eye through a piece of smoked glass. All spots appear to move across the Sun's disc from east to west. Many single spots and groups of spots which have passed from sight around the Sun's western limb have been recognized on their reappearance, after about two weeks' time, at the eastern limb. It has been concluded from the recurrences of such groups that the period of the Sun's rotation is about 27 days. To be more precise, the interval elapsing between two successive passages of a spot across the Sun's central line is a little less than 27 days for spots on the Sun's equator, and this interval increases to more than 28 days for those midway between the equator and the poles. Spots are rarely observed any nearer to the Sun's poles. The outlines of sunspots are not the same; some do not reappear at all, and others exist through several rotations, but very seldom indeed do they persist for longer than half a year.

Since the conditions on the Earth depend so much on the Sun, any effects of sunspots on terrestrial phenomena have been eagerly sought. These investigations have led to the idea that the Sun ejects, from well-defined areas on its surface, clouds or streams of particles—electrons, ions and molecules. These streams finally enter the Earth's atmosphere, but do not penetrate far downward, because they are stopped by the atmosphere before they approach within 50 miles above the Earth's surface. (This is, by the way, not the only case in which the atmosphere protects us from outside influences; meteors, for example, are dissipated in the air and thus seldom reach the Earth's surface, and the powerful ultra-violet radiation of the Sun is intercepted by a small quantity of ozone in the upper atmosphere.)

The assumption of the solar streams is based on indirect information, depending mainly on two phenomena. One is the glow excited in rarefied air by the impact of the solar particles—observed by us as aurora. The other is the system of electric currents set up by the solar particles in the highest regions of the atmosphere, the effects of which we observe in irregular changes, or disturbances, of the Earth's magnetic force. We shall deal here only with the latter, since they are continuously recorded at more than forty observatories distributed over the entire globe, while aurora is almost exclusively seen in the polar regions, and even there only at night.

In order to trace the solar influence on the Earth's magnetism, we may consider the varying degree of magnetic

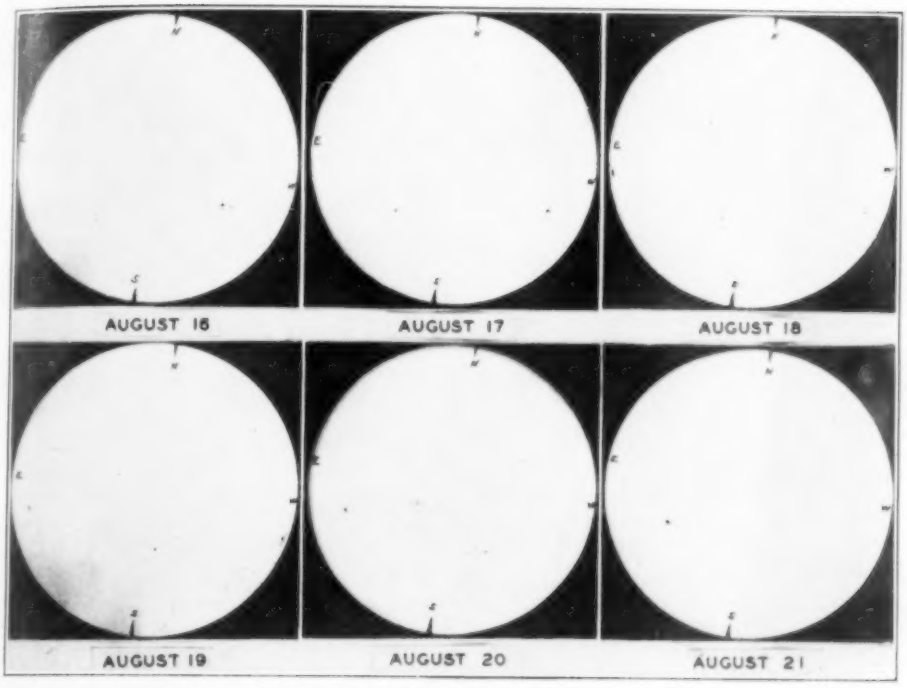

FIG. 1. SUNSPOTS MOVING ACROSS SUN'S DISC

PHOTOGRAPHS OF THE SUN TAKEN AT MOUNT WILSON OBSERVATORY ON SIX CONSECUTIVE DAYS, FROM AUGUST 16 TO 21, 1927.

disturbance. During magnetically quiet periods, only regular changes are observed, which repeat themselves day after day. Violent disturbances are called magnetic storms (though no relation to weather and especially to thunder-storms has been found); at times they break out simultaneously all over the Earth and may last for about two days. Such storms occur only from two to five times per year and are always accompanied by pronounced auroras and by currents disturbing cable transmission. Some of these have been definitely connected with the passage of large sunspots near the center of the Sun's disc, or with sudden solar flares. The intermediate stage of moderate disturbance is, however, a quite common phenomenon, about as frequent as polar aurora, which was observed on the Shetland Islands, in the winters 1924–28, on nearly half of all nights on which moonlight or heavy clouds did not prevent observation.

It is important to have a measure for the magnetic activity, that is, the intensity and frequency of magnetic disturbances during a given interval. This is most conveniently obtained by the method of characterization. Each observatory assigns, on the basis of the character of its magnetic records, to each interval of 24 hours between successive Greenwich midnights, a character-number, namely, "0" for quiet, "1" for moderately disturbed, and "2" for greatly disturbed days. The average number for all collaborating observatories is called the international magnetic character-number. This is represented daily in the accompanying Fig. 2 by suitably graded symbols (gray for quiet, black for disturbed days). This

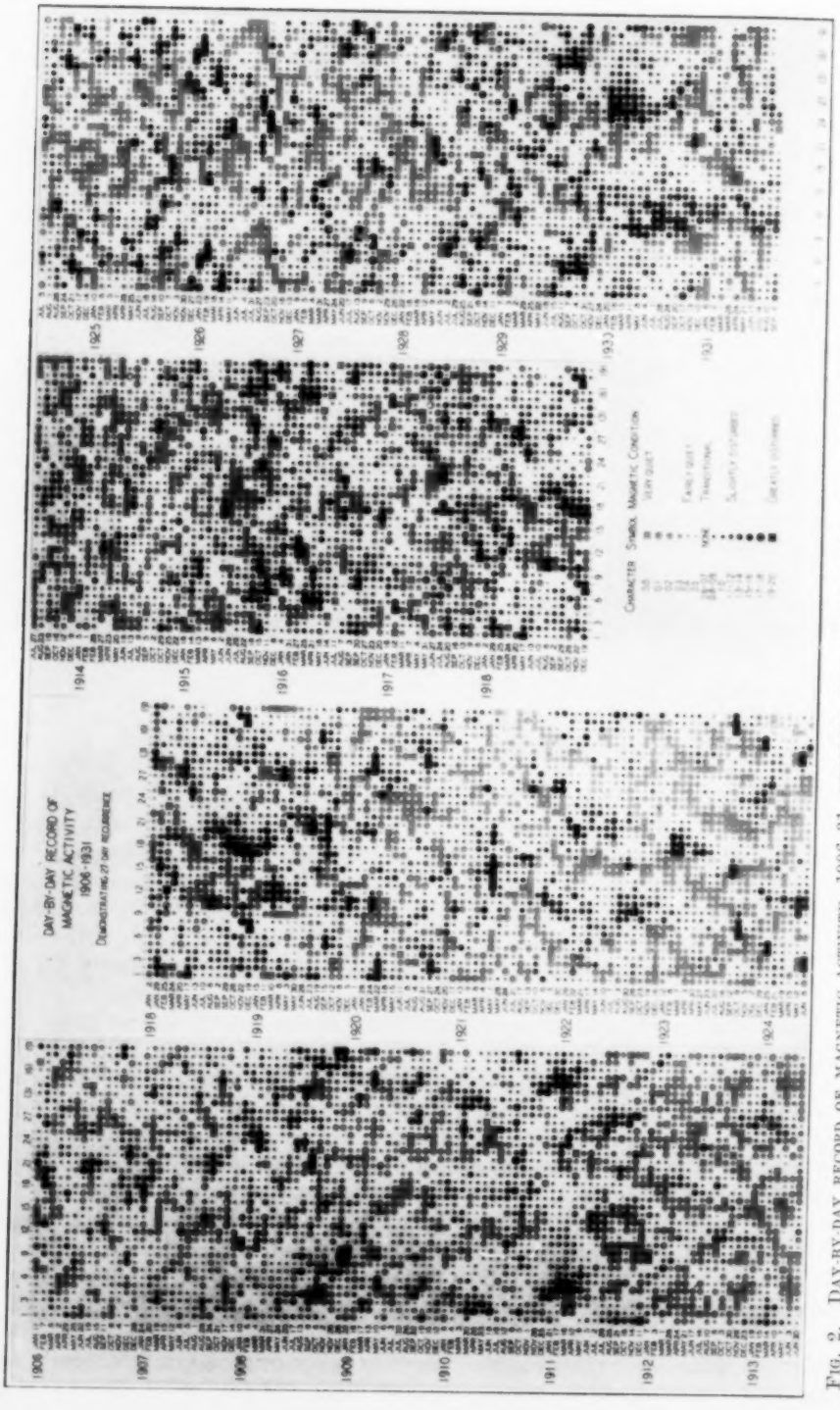

FIG. 2. DAY-BY-DAY RECORD OF MAGNETIC ACTIVITY, 1906–31, SHOWING INTERNATIONAL MAGNETIC CHARACTER FIGURES BY SYMBOLS ARRANGED IN ROWS BEGINNING WITH DATES SHOWN AT LEFT OF EACH ROW, EACH DATE BEING 27 DAYS LATER THAN THE DATE ABOVE IT, AND DEMONSTRATING 27 DAY RECURRENCE DUE TO SUN'S ROTATION.

figure constitutes a complete record of magnetic activity since 1906, the year in which the scheme of characterization was put into effect.

The record, which contains nearly ten thousand symbols, reads like a book. The date of the first day in each row is indicated on the left, each successive row beginning 27 days later; at the end of each row the first nine days of the next row have been repeated in order to emphasize the continuity of the series. To facilitate reference, the days in each row are numbered 1 to 27. As it happens, considering the transitional condition as being magnetic character-number 0.6 to 0.7 and for which days the space is left blank, the remaining symbols total about as many black as gray on the chart. The years 1906–31 have been arranged in two vertical rows, so that intervals which are eleven years apart appear side by side.

The repetition of quiet and disturbed days after a rotation of the Sun, the 27-day recurrence-phenomenon, is clearly indicated in the record by the distinct vertical columns (sequences) in which the gray and black symbols arrange themselves. Some of these sequences last for a year or even longer. If the recurrence-interval were shorter or longer than 27 days, this would appear in a definite slant of the columns. Thus, a 28-day interval seems to be indicated in the minor disturbances during the second half of 1913 (after day 13), but otherwise 27-day intervals are predominant.

The so-called 11-year sunspot-cycle is also noticeable in the diagram, by the prevalence of gray symbols (quiet days) in the years with few sunspots (about 1911 and 1923), and of black symbols (disturbed days) in the years with many sunspots (about 1906, 1917 and 1928). However, there is no row in the diagram which contains only gray or only black symbols. On the contrary, pronounced sequences of quiet days per-

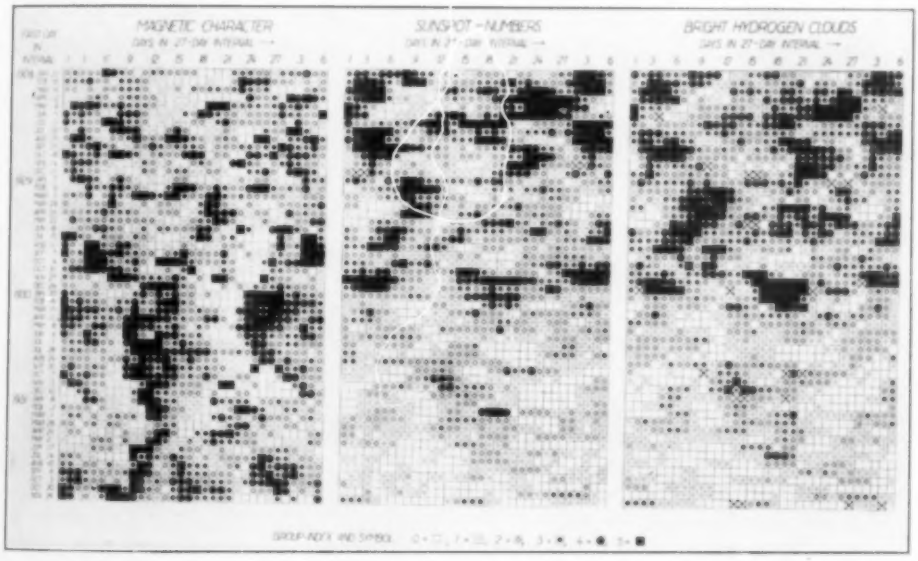

FIG. 3. DAY-BY-DAY RECORD, 1928–31, OF INTERNATIONAL MAGNETIC CHARACTER-FIGURES, RELATIVE SUNSPOT-NUMBERS FOR CENTRAL ZONE, AND SOLAR INDICES FOR BRIGHT HYDROGEN CLOUDS IN CENTRAL ZONE, EACH EXPRESSED BY ONE OF SIX SYMBOLS ARRANGED TO SHOW 27-DAY RECURRENCE-PHENOMENON—THE CROSSES MARK THOSE DAYS FOR WHICH THERE WERE NO SOLAR OBSERVATIONS.

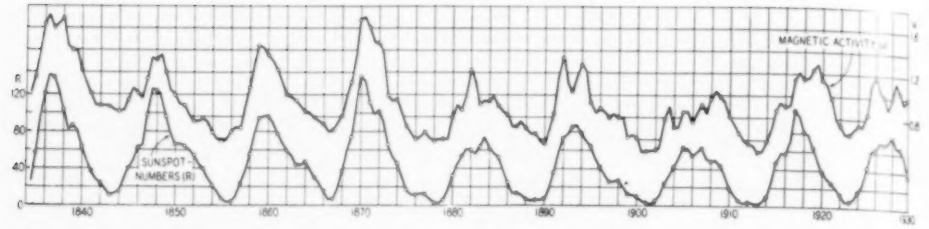

FIG. 4. ANNUAL MEANS OF MAGNETIC ACTIVITY AND RELATIVE SUNSPOT-NUMBERS, 1835–1930. (THE POINTS MARKED BY SMALL CIRCLES ARE THE USUAL YEARLY MEANS FOR JANUARY TO DECEMBER.)

sist near a sunspot-maximum (for instance, in 1917, 1918 and since 1926), and sequences of disturbed days persist near a sunspot-minimum (1911 and 1923). Accordingly, the Sun's surface can never be everywhere quiet or everywhere agitated.

Two or more sequences often run simultaneously, but they never divide the 27-day interval into regular subdivisions. This contradicts the assumption, sometimes made, that the Sun's surface shows a systematic pattern.

Besides the general relationship between sunspots and magnetic activity in the 11-year cycle, exact correspondence is sometimes found even in individual cases. For instance, the greatest storm on the record, that of May 13–16, 1921, was accompanied by the passage of an extremely large, but short-lived, group of spots across the center of the Sun's disc on May 14.

If, however, we attempt to coordinate the individual quiet or disturbed magnetic sequences to similar recurrent spotless or spotted regions on the Sun, we meet, on the whole, with a striking disappointment. In the first place, the magnetic sequences are mostly longer than the life of spot-groups, which are rarely observed to return more than four or five times. Moreover, several magnetically disturbed sequences persisted through times when, for several weeks in succession, not a single sunspot was visible, as, for example, the fine sequence in the first half of 1923 (day 18), with its well-defined occurrences after 27 days.

As a test of this, the diagram (Fig. 3) was prepared in the same manner as

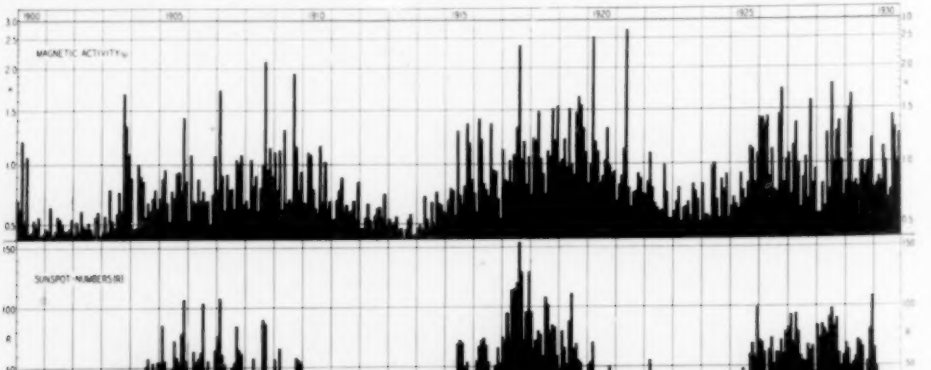

FIG. 5. MONTHLY MEANS OF MAGNETIC ACTIVITY ANN OF SUNSPOT-NUMBERS, 1900–30.

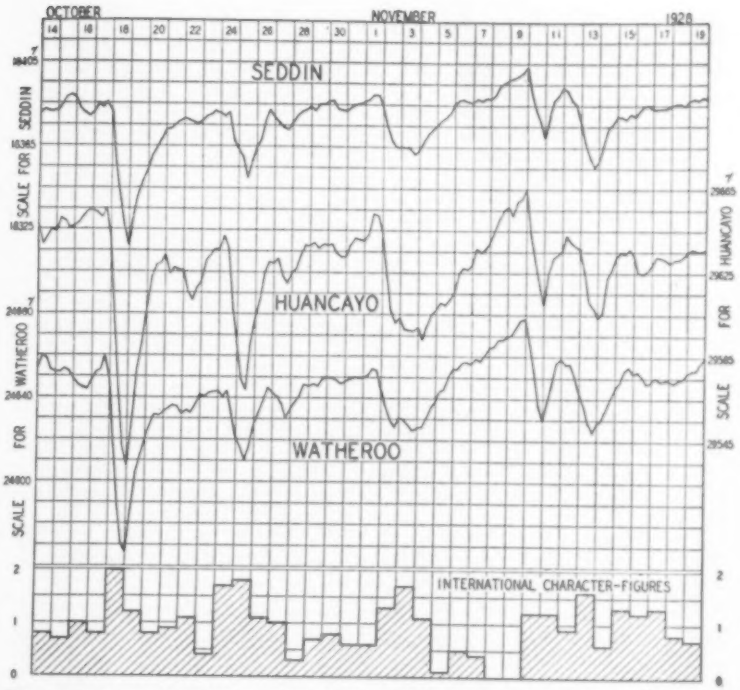

FIG. 6. THE WORLD-WIDE NATURE OF POST-PERTURBATION INDICATED BY SIMILARITY OF THREE CURVES SHOWING THE DAILY MEANS MAGNETIC NORTH COMPONENT AT SEDDIN (GERMANY) AND HORIZONTAL INTENSITY AT HUANCAYO (PERU) AND AT WATHEROO (WESTERN AUSTRALIA), OCTOBER 14 TO NOVEMBER 19, 1928. (PLOTTED MEANS FOR CONSECUTIVE 24-HOUR PERIODS, 6 HOURS APART; THOSE FOR 24 HOURS CENTERED AT GREENWICH MIDNIGHT COINCIDE WITH VERTICAL LINES.)

Fig. 2. The left-hand diagram is a repetition on a larger scale, of the corresponding part, for the three years 1928–30, of Fig. 2 for the international magnetic character-numbers. The other two represent solar phenomena, as obtained by direct astrophysical observations of a central disc of half the Sun's diameter (this being the part of the Sun which is most likely to exert an influence on the Earth), namely, relative number of sunspots and the intensity of bright markings as seen in the light of the hydrogen-line by means of Dr. Hale's ingenious spectrohelioscopes. Again, gray symbols denote quiet conditions, and black symbols denote high activity.

Comparison of the three diagrams shows that sequences in one of the solar phenomena can easily be recognized in the other; sunspots and bright hydrogen-clouds occur, therefore, in about the same regions of the Sun. The pronounced magnetic sequences can not, however, be recognized in either of the solar phenomena—even if the possibility of a lag betweeen a solar outburst and its action on the Earth is taken into account. This is confirmed also for other solar phenomena and leads to the following conclusion:

Terrestrial-magnetic activity reveals persistent solar influences which are distinctly recognized as such by the 27-day recurrence due to the Sun's rotation. Magnetic activity must, therefore, be attributed to some action of fairly defi-

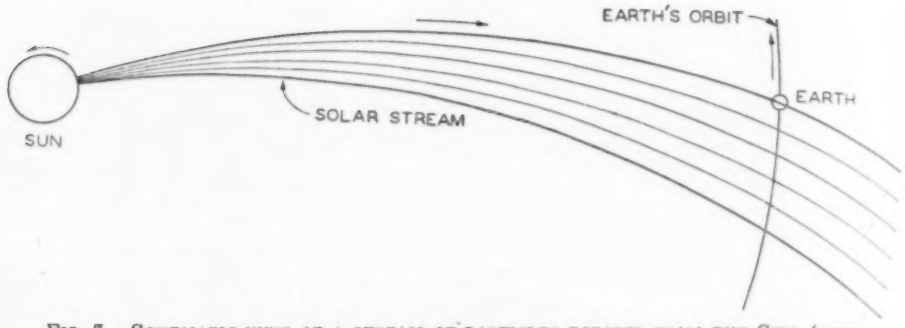

FIG. 7. SCHEMATIC VIEW OF A STREAM OF PARTICLES EJECTED FROM THE SUN (AFTER S. CHAPMAN).

nite regions on the Sun's surface—we call them M-regions. These M-regions can not, at present, be individually identified with any of the phenomena which are directly observed on the Sun. In the averages taken over a number of years, however, the M-regions must vary in area like the sunspots, since magnetic activity shows the 11-year cycle quite distinctly.

This 11-year cycle is shown both in magnetic activity and relative sunspot numbers since 1835 in annual means (Fig. 4) and in monthly means (Fig. 5). Another more objective measure of magnetic activity is represented in these figures; it is based on the fact that the horizontal portion of the Earth's magnetic force varies from day to day very similarly all over the globe, rapidly decreasing during a magnetic storm, and slowly recovering afterward (Fig. 6). The u-measure of activity is (roughly defined) the average change from day to day, regardless of sign, of the magnetic force near the Earth's equator.

The fair parallelism of magnetic activity and sunspots, as shown in Figs. 3 and 4, appears to be absent in certain intervals, for instance, in the three years 1918–20 and 1928–30. The failure of other solar phenomena to show, in the latter interval, better relations to magnetism than sunspots, is the basis of the conclusions drawn above. On the other hand, the good agreement between sunspots and terrestrial magnetism in the other parts of the long series 1836 to 1930 is striking evidence that solar and terrestrial relationships are not steady and can not be fully obtained from the study of short series of observations.

If the solar particles travel in about one and a half days to the Earth, they would form a stream like that shown in Fig. 7, since the source of emission rotates with the Sun. This stream is perhaps not continuous, but may be only a succession of separate clouds. Though each single particle is emitted nearly radially, direct from the Sun's surface, the whole stream seems to rotate around the Sun just like water from a garden hose, and would sweep across the Earth once in about every 27 days, as long as the active region on the Sun persisted. Between the first impact and the time at which the Earth is completely enveloped by the storm, less than one minute elapses, which explains the practically simultaneous beginning of many magnetic storms. The detailed movements of the particles are very complicated, especially near the Earth, where they are deflected by the Earth's magnetic forces. S. Chapman and C. Störmer have attacked this difficult problem from different view-points.

Whatever detailed theory of magnetic disturbances may be evolved, it is clear that magnetism provides us with information regarding fairly persistent solar phenomena, restricted to varying, but always well-defined, regions on the Sun's surface. These are not only of interest for the study of the Sun, because direct astrophysical observations do not reveal them as yet, but are of even greater interest from the terrestrial standpoint, because magnetism records these solar influences only in so far as they actually affect our globe. This information will be useful in the study of radio-transmission, because radio-waves are transmitted around the Earth in the same upper layers of the atmosphere in which the magnetic variations are produced. Beyond faint indications of an 11-year cycle, no such positive proof, however, as yet exists that weather—in other words, the lower atmosphere—is influenced by solar changes in the same straightforward manner as these outermost regions, which are, of course, most sensitive to cosmic influences.

A more extended account of the above will be found in the article by J. Bartels in volume 37, pages 1 to 52, of the March, 1932, issue of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. Other references bearing on the subject-matter above are: S. Chapman and V. C. A. Ferrero, *Journal of Terrestrial Magnetism and Atmospheric Electricity*, vol. 36, 77–97, 171–186 (1931); vol. 37, 147–156 (1932), and C. Störmer, *Journal of Terrestrial Magnetism and Atmospheric Electricity*, vol. 35, 193–208 (1930).

THE PROPOSED REVISION OF THE GREGORIAN CALENDAR[1]

By HENRY W. BEARCE

U. S. BUREAU OF STANDARDS

WITHIN the past few years much has been written on the subject of calendar revision, and many plans have been proposed for revising and simplifying the Gregorian calendar, by means of which most of the civilized world, including the United States, reckons the passage of time and records the order of events.

The matter has been considered by a special committee of the League of Nations, national committees have been organized in the United States and several other countries, and bills[2] have been introduced in Congress, all looking toward a revision of our calendar.

At the October, 1931, meeting of the Committee on Communications and Transit of the League of Nations, at which 44 nations were represented, it was concluded that disturbed conditions rendered the time inopportune for a general simplification of the calendar. Hope was expressed that general action might be taken before the year 1939, that being the first year after 1933 in which the year will begin on Sunday.

In spite of the publicity that has been given to the question of calendar revision, it may still be said that vital interest in the matter is confined to a relatively small group. The vast majority of persons, while not opposed to calendar revision, are indifferent to it. The defects of our present calendar, when brought to their attention, are readily admitted, but familiarity, through a lifetime of use, tends to minimize the importance of these defects. Probably most of us would prefer to continue to use our present calendar, imperfect though it is, rather than go to the necessary trouble of learning a new one.

If intelligent and well-considered action on the calendar is to be taken before 1939, or at any subsequent time, it is important that a considerable percentage of the people of all nations concerned become somewhat familiar with the more important of the many considerations involved in calendar revision. The day has passed in which calendar revision is likely to be brought about as a result of the efforts or interest of a single individual or even of a small group. The interest must be widespread and the efforts well directed in order to overcome the natural inertia of the public mind and of legislative bodies.

The origin and history of our present (Gregorian) calendar and that of earlier calendars have been so extensively and so ably discussed by others that further treatment of that phase of the subject seems unnecessary. It is perhaps sufficient to say that the Gregorian calendar now in use in the United States and a large part of the rest of the world was adopted in Catholic countries in 1582; in Great Britain and her colonies, including the United States, in 1752[3]; in

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] H. R. 12221, May 29, 1922; S. 2862, Jan. 27, 1928; H. J. Res. 334, Dec. 5, 1928.

[3] In Great Britain and her Colonies the calendar year 1751 ended with December 31, and the year 1752 began on January 1. Prior to that time the British civil year had begun with March 25 (except that in Scotland the civil year, from 1700 to 1751, began on March 1). The year 1751 was, therefore, a short year. Having begun March 25 and ended De-

Russia in 1917; and in certain European countries adhering to the Greek Orthodox Church, in 1923.

The Gregorian calendar is thus seen to have served a considerable proportion of humanity over a relatively long and critical period of time. It would seem wise, therefore, before discarding or materially changing it to consider carefully whether the proposed changes may reasonably be expected to result in definite improvement. The calendar is too vital an instrument to be held lightly, or to be altered for the amusement or even for the benefit of a small group of enthusiasts or reformers.

As a first step in the process of arousing interest in any cause or proposed reform it is usually regarded as good practice to set forth the evils of the existing situation. So in this instance I shall begin by pointing out some of the defects of our present calendar. No attempt will be made to place these defects in the order of their relative importance, as such an arrangement would be largely a matter of personal opinion.

It is my purpose to treat the subject from the standpoint of the analyst rather than from that of the advocate of any particular plan or revision. It is probably inevitable, however, that my personal choice of a plan of revision will be indicated.

The principal defects of our present calendar may be listed as follows:

(1) The calendar year is of non-uniform length; ordinary years containing 365 days, and leap years 366 days.

(2) The calendar year is not evenly divisible into weeks, ordinary years containing 52 weeks and 1 day, and leap year 52 weeks and 2 days.

(3) The calendar year is not divisible, by months, into halves and quarters of uniform length.

(4) The months are of unequal length.

(5) The months are not evenly divisible into weeks.

(6) The date of Easter and other "movable festivals" is not fixed.

The above principal defects are more or less closely interrelated, and out of them flow a wide variety of secondary defects or inconveniences. For example, the first defect comes from the fact that the astronomical or tropical year does not contain an integral number of days. The length of the tropical year being slightly less than $365\frac{1}{4}$ days (365.2422 days, more exactly), it is apparent that if the calendar year is to contain an integral number of days the best that can be done is to make some years contain 365 and others 366 days. A more detailed discussion of the leap-year rule, and the length of the tropical year, will be found at a later point in this paper.

From the second defect, the fact that the calendar year is not evenly divisible into weeks, it follows that successive years begin on different days of the week. For example, 1931 began on Thursday, 1932 on Friday and 1933 will begin on Sunday. The two-day progression between January 1, 1932, and January 1, 1933, comes from the fact that 1932 is a leap year. The two-day

cember 31, it contained no January or February and (except in Scotland) no March 1 to 24, inclusive. 1752 was also a short year in Great Britain and her colonies, since 11 daydates were dropped from the calendar in September of that year. There were no days designated as September 3 to September 13, inclusive, of that year. There was no interruption of the regular succession of the days of the week. Wednesday, September 2, was followed by Thursday, September 14. 1752 was a leap year under the new calendar, and if 1748 was a leap year under the old calendar, as it appears to have been, then these two leap years were separated by a period of only three years instead of the usual four years. That is, February, 1752, under the new calendar, contained 29 days, whereas, had the old calendar been continued, that month would have fallen in 1751 and would have contained 28 days only. It is thus seen that under the Gregorian calendar each leap year, beginning with 1752, has fallen one year earlier than it would have fallen had the old calendar been continued.

progression extends from February 29, 1932, to February 28, 1933, after which the progression of any given date through the week will be restored to one day per year, and this one-day progression will continue until again disturbed by February 29, 1936. A similar wandering, or progression, to various days of the week occurs, of course, for all other dates in the same way and for the same reason that it does for January 1.

This progression of any given date through the various days of the week is the cause of the ever-changing school schedules, vacation periods, etc., and it can be overcome only by some plan that will make all years begin on the same day of the week.

The third defect, *i.e.*, quarters of unequal length, comes from the fact that the months are of unequal length and irregular arrangement. In an ordinary year the quarters are as follows: First quarter, 90 days; second quarter, 91 days; third quarter, 92 days; fourth quarter, 92 days. This gives 181 days to the first half, and 184 days to the second half of the calendar year. In leap years, the first quarter is increased to 91 days and the first half year to 182 days.

The fourth defect, *i.e.*, months of unequal length, is the most obvious, and to many, the most serious defect of our present calendar. In childhood we learned that. "Thirty days hath September, April, June and November," etc., and by resorting to this rather cumbersome device we are able to decide as to the length of the various months. This inequality of the months makes direct comparison of monthly statistics impossible. Such statistics must be reduced to a uniform basis before accurate comparisons can be made.

The fifth defect, *i.e.*, the month not evenly divisible into weeks (except February of an ordinary year), is also generally recognized as a defect, and this also is regarded by some writers on calendar reform as of great importance. The question of its importance will be given further attention at a later point.

The sixth defect, *i.e.*, the wandering of Easter to various dates from March 22 to April 25, both dates inclusive, I shall not discuss in detail, except to say that the date of Easter and other movable church festivals can be fixed under a 12-month or a 13-month plan with equal facility. It is believed that the problem of selecting a suitable date for Easter, under the revised calendar, can safely be left to the properly constituted authorities of the several branches of the Christian Church.

Having pointed out some of the principal defects of our calendar, let us now consider what, if anything, can be done to correct or minimize these defects. In any proposed revision it is important that in our zeal for change we do not simply replace one defect with an equal or greater one. The only justification for changing anything that has served a large section of humanity long and satisfactorily is to secure something more satisfactory in its place; and since the function of a calendar is to serve as an accurate and convenient means of reckoning time and recording events, it follows that our only hope of securing a calendar more satisfactory than our present one lies in our ability to devise one that is more accurate or more convenient than the one now in use.

On the basis of accuracy our present calendar, as pointed out by Marvin,[4] is susceptible of slight improvement.

The passage of time, as indicated by watches and clocks, and by the calendar, is usually expressed in terms of the mean solar day and its subdivisions and multiples, the mean solar day being defined as the average time it takes the

[4] C. F. Marvin, *Popular Astronomy*, May, 1923, and "Standards Yearbook" (Bureau of Standards), 1929.

earth to make a complete rotation about its axis. As a matter of convenience, the calendar year is made to contain an integral number of mean solar days. It would obviously be inconvenient and confusing to have the calendar year begin at any time other than at the beginning of a day, *i.e.*, at 12 o'clock midnight.

The seasons are, of course, governed by the position of the earth with reference to the sun, and the tropical year is defined as the time it takes the earth to make a complete journey around the sun. This period is not divisible into an integral number of mean solar days. That is, in the time required by the earth to make a complete journey around the sun, the earth does not make an integral number of complete rotations about its own axis. This incommensurability of the tropical year and the mean solar day is the cause of much of the difficulty in calendar-making.

Length of the Tropical Year

According to mathematical astronomers the length of the tropical year is represented by Newcomb's equation, $L = 365\ d + f - b\ t$, in which f and b are constants having the values, $f = 0.24231545$, $b = 0.0000000614$, and t is the time in years counted from the beginning of the Christian era. On this basis the present length of the tropical year is 365.24220 days, and the year is growing shorter at the rate of 0.53 second per century.

Length of the Calendar Year

Since the calendar year contains sometimes 365 and sometimes 366 days, the average length is, of course, determined by the relative frequency of occurrence of these two numbers, that is, by the leap-year rule.

Under the Gregorian leap-year rule every fourth year is a leap year, except that of the century years only those years that are evenly divisible by 400 are leap years. That is, in a period of 400 years, 3 years that would normally be leap years, under the 4-year rule, are not counted as leap years. The average length of the calendar year under the Gregorian leap-year rule is, therefore,

$$L_{Gregorian} = 365 + 1/4 - 3/400 \text{ days}$$
$$= 365.24250 \text{ days}$$

On comparing this value with the length of the tropical year, as calculated from Newcomb's equation, it is seen that the calendar year is longer than the tropical year at the present time by 0.0003 day, or 25.92 seconds. Moreover, if the tropical year is shortening and if it continues to shorten in accordance with Newcomb's equation, this difference will increase as time goes on and in the course of some 3,300 years from the time when the two were in agreement an error of a full day will have accumulated as a result of this increasing difference between the tropical year and the Gregorian calendar year.

Using Newcomb's equation to project back into the past, it is found that in 3006 B. C. the length of the tropical year was 365.24250 days. That is, at that time the length of the tropical year was the same as the average length of the calendar year under the Gregorian leap-year rule. The Gregorian calendar was, of course, not in use at that time, and by the time it was adopted, in 1582 A. D., the tropical year was already shorter than the Gregorian calendar year by some 24.3 seconds.

Because of this error in the average length of the Gregorian calendar year, as compared with the present length of the tropical year, it has been suggested by Marvin that in revising our calendar we should at the same time adopt a more nearly correct leap-year rule. A more nearly correct rule has, in fact, already been tentatively put into effect by the Greek Orthodox Church, which in its adoption of the Gregorian calendar did

not adopt the Gregorian leap-year rule, but in its stead, a more accurate one under which in a period of 900 years, 7 quadrennial years that would normally be leap years are not counted as leap years. Under this leap-year rule the average length of the calendar year is

$$L_{(Gk.)} = 365 + 1/4 - 7/900$$
$$= 365.24222 \text{ days}$$

It will be noticed that, to four decimal places, this value is in agreement with the present length of the tropical year.

Obviously, if the tropical year continues to shorten in accordance with Newcomb's equation this leap-year rule will, in the course of time, become incorrect even as the Gregorian rule has already become incorrect, and it in turn will need to be revised. However, it seems likely that before that time astronomers will have determined new and more exact values for the constants of Newcomb's equation, so that revision may be necessary on that account.

Various leap-year rules are discussed in detail by Marvin in the papers above referred to.

With further reference to the supposed necessity for adopting a more exact leap-year rule, it should, perhaps, be pointed out that this may be regarded by some as a case of "straining at a gnat and swallowing a camel," since even with a perfect leap-year rule the calendar and the tropical year are bound to be "out of step" by at least ½ day once in each 4-year period. For example, if the calendar year and the tropical year are "in step," that is, begin at the same time, at the beginning of a 4-year period, they will be "out of step" by ¼ day at the end of the first year, ½ day at the end of the second year, ¾ day (or ¼ day in the opposite direction) at the end of the third year, and again "in step" at the end of the fourth year. It may, therefore, be unwise to be troubled over-much by a cumulative error of one day in about 3,300 years. It might be just as satisfactory to correct the Gregorian leap-year rule by simply dropping out an extra leap year once in each 3,300 years. The average length of the calendar year would then be $365 + 1/4 - 3/400 - 1/3300$, or 365.24220 days. This value is in agreement with the present length of the tropical year, as calculated at an earlier point in this paper. The discrepancy that has already accumulated could be corrected by counting as an ordinary year some year in the near future, say 1940, that would normally be counted as a leap year.

Let us now turn to consideration of the second ground on which revision of our present calendar may properly be urged; that is, increased convenience.

The principal defects of the Gregorian calendar having already been pointed out, attention will now be given to means by which these defects may, in whole or in part, be overcome.

The many plans of revision that have been proposed, while differing in detail, are nearly all reducible to two general plans; first, the 13 equal months plan, and second, the 12 month, equal quarters plan.

The ideal arrangement would, of course, be a calendar year of 12 months, of 28 days each, since it would provide a complete and consistent series of time units, from the second to the year, with each unit containing an integral number of the next smaller unit.

The only difficulty with this plan is that it wouldn't work. Such a calendar year would be about 4 weeks shorter than the tropical year, and as a result, within a very few years, the 4th of July would come in the winter, and Christmas in the summer. There would be no fixed relation between the calendar and the seasons. Such a calendar would, of course, not be at all satisfactory.

We must, then, content ourselves with some plan that will keep the calendar

year as nearly as practicable equal to the tropical year, and at the same time be as convenient as possible.

We are, therefore, inevitably driven back upon one or the other of the two plans already mentioned; namely, the 13 equal months plan, or the 12 month, equal quarters plan. The practical problem is to decide which of these two plans will result in the greatest net gain, from the standpoint of convenience.

It has already been shown that the tropical year contains about 365¼ days, and that by the adoption of a suitable leap-year rule the average length of the calendar year can be made equal to that of the tropical year to any desired degree of approximation. Since it is important to have the beginning of the calendar year coincide with the beginning of a day, that is, to have the calendar year contain an integral number of complete days, it is obviously necessary to have some years contain 365 and others 366 days. In this respect there is no possibility of improvement through calendar revision, since the length of the tropical year and of the mean solar day are beyond the control of man. If they are "defective," from our point of view, it is unfortunate; there is nothing we can do about it.

The second defect of our calendar, that is, that the calendar year is not evenly divisible into weeks without a remainder, is the result of the simple mathematical fact that neither 365 nor 366 is evenly divisible by 7. There is a remainder of 1 day in ordinary years and 2 days in leap years, as already pointed out, and this excess of 1 day or 2 days is what causes the progression of any given date to various days of the week. The only way it can be overcome is by resorting to some device or subterfuge by means of which one week in each ordinary year and two separate weeks in each leap year are made to contain eight 24-hour periods each instead of the usual seven 24-hour periods. A wide variety of plans have been proposed for accomplishing this; "blank days," "double days" "days without date," etc. The usual, and most feasible, suggestion is that these 48-hour periods be placed at the end of December each year, and at the end of June in each leap year.

The method of designating the second 24-hour period of these suggested 48-hour "days" is not important, except that the designation must be definite and specific. They can not be "blank days" or "days without date," since events will occur, persons will be born, others will be married, still others will die during these 24-hour periods, as in any other similar period, and records must be as specific and definite as for any normal day. A satisfactory designation would seem to be "Sat. Dec. 31," this day to follow "Sat. Dec. 30," each year; and "Sat. June 31," to follow "Sat. June 30" of each leap year.

Obviously such a device would make the calendar year evenly divisible into weeks, with no remainder, and all years would then begin on the same day of the week.

If such a change should be put into effect at the appropriate time, say 1933 or 1939, all subsequent years would begin on Sunday and end on Saturday. Such a change would apply equally well to a 13 equal months calendar or to a 12 month, equal quarters calendar.

Objection has been raised by certain religious groups, notably Jews, Seventh Day Baptists and Seventh Day Adventists, to the adoption of any plan of revision that will interrupt the regular succession of the 7 days of the week. From the foregoing it is apparent that if a revision plan is to be adopted such that all years will begin on the same day of the week, whether it be a 12-month or

a 13-month plan, this objection, if it be an objection, will have to be tolerated.

The principle of the 48-hour period under a single day name is by no means new. At the time of Moses there were double days at the feast of the Passover. At the present time there is an almost exact analogy in the reckoning of time at the international date-line. When this line is crossed from west to east a second 24-hour period is given the same day-name (and date) as the 24-hour period just passed; that is, a day is repeated. On crossing the line in the opposite direction a calendar day is omitted. When a traveler from east to west passes from one standard time zone into the next he sets his watch back an hour and thus has two one-hour intervals in the period of one hour by his watch. These variations from the regular progress of time are not usually regarded as sacrilegious or in violation of divine law. They are regarded, rather, as convenient methods of bringing about standardization in the reckoning of time. It would seem that the proposed "double-day" might reasonably be regarded in the same light.

So far, then, there is no choice between the two proposed plans. With the third defect, we come to the parting of the ways, since what applies to one plan will not apply to the other. We must, therefore, decide which characteristics of a calendar are to be regarded as most important. For example, is it more important that all months be alike and each month evenly divisible into weeks, even though this arrangement makes necessary the addition of a new month; or is it more important to retain the 12-month calendar, to which we are accustomed, making the quarters equal, and the months as nearly equal as is possible under a 12-month plan?

Under the 13 equal months plan each month would contain 28 days, or 4 complete weeks, and all months would begin on Sunday. The calendar for all months would be as follows:

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28*

Note.—This arrangement is usually designated as the International Fixed Calendar.

* In order for all years to begin on Sunday, the last day of each year (Sat. Dec. 28), and the last day of some other month (*e.g.*, Sat. June 28), of each leap year, must contain 48 hours instead of the usual 24.

Under this plan a new 28-day month would have to be added at some point in the calendar. One suggestion is that it be inserted between June and July and that it be designated "Sol," as the summer solstice would fall within this period.

The most satisfactory arrangement for a 12 month, equal quarters plan, is undoubtedly that in which each quarter contains one month of 31 days followed by two months of 30 days each. This is often referred to as the "Swiss Plan," and more recently as the "World Calendar." Under the original "Swiss Plan" each quarter began on Monday and ended on Sunday, and the third month contained 31 days. The arrangement is shown on page 507.

It will be seen that the first month of each quarter, *i.e.*, January, April, July and October, begins on Sunday, contains 31 days with 5 Sundays and 26 week days, and ends on Tuesday; that the second month of each quarter, *i.e.*, February, May, August and November, begins on Wednesday, contains 30 days with 4 Sundays and 26 week days, and ends on Thursday; that the third or last month of each quarter, *i.e.*, March, June, September and December, contains 30 days with 4 Sundays and 26 week days, and ends on Saturday.

January
April
July
October

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February
May
August
November

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

March
June
September
December

Su	M	Tu	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30*

*In order for all years to begin on Sunday the last day of each year (Sat. Dec. 30), and the last day of June (Sat. June 30), of each leap year, must contain 48 hours instead of the usual 24.

Under this plan the four quarters would be equal, the two halves would be equal, corresponding months of each quarter and of all years would be equal, and for many industrial purposes all months would be equal, since each month would contain 26 week days. For certain other purposes the months would not be equal, since some would contain 30 and others 31 days.

Advocates of the 13-month plan lay great stress upon the importance of having all months of equal length, in order that for statistical purposes they may be directly comparable. It might be well to inquire whether making them the same length would in fact make them comparable. Obviously, because of seasonal variations, comparisons between December and June, for example, will, in many cases, be of little value, even though each month be made to contain 28 days. In many cases monthly statistical comparisons are valid only between corresponding months, for example, June with June, December with December, etc. Such comparisons are as convenient and as valid under the proposed 12-month plan as under any possible 13-month plan.

In general, statistical comparisons are made between periods recently closed and corresponding periods of former years. It is important, therefore, that current statistics be kept in terms of time intervals that have as nearly as possible exact counterparts in former years. For example, statistical comparisons can be made between August, 1931, and August of any other year without serious error. If correction is necessary in order to take account of the differences of industrial or business value of the different days of the week, this correction can readily be made. That is, if our calendar is revised on the basis of a 12-month, equal quarters plan, comparison of statistics for any month under the new plan, with those for the corresponding month under our present calendar, would not be seriously interfered with. Direct comparison of unreduced monthly figures for corresponding months would in many cases be satisfactorily accurate, and after the lapse of a few years, so that comparisons were entirely within the new calendar, they would be entirely accurate.

On the other hand, what would be the situation if we should adopt the 13-month plan? Corresponding months under the new calendar would, of course, be comparable; but what of comparisons between the new 28-day calendar months and corresponding periods of the past? Obviously, figures would not be available for corresponding periods of the past. How, then, could comparisons be made? The answer is that they could not be made without so many adjustments, approximations and assumptions that the comparative figures, when finally arrived at, would be of little value.

The case against the 13-month calendar from the statistical standpoint is well presented by Professor Clark Warburton in the closing paragraphs of his article in the August, 1931, number of the *Journal of Calendar Reform:*

> To re-compute the numerous indexes of prices, industrial production and other phases of economic activity would be a costly procedure justified only by definite and great advantages. In the case of many of the statistical series linking the present with the past, it would be impossible to convert the records of the past into a form comparable with the present.
>
> The next few years are certain to be critical years in the world's history. Economic changes are extremely rapid. Economic systems are challenging each other. There is great uncertainty. Popular clamor has begun for economic stabilization, for reform of the capitalist system so as to provide continuous and adequate incomes for wage-earners, and for the future development of productive facilities in accord with a national plan based on the needs and desires of the people.
>
> To meet this demand for business stabilization and for national economic planning it is essential that economists and business men have during the next few years all the aid possible from past business records. A radical change in the calendar would seriously reduce the usefulness of these records and thus hamper the adjustment of business to world needs at a critical time in the advance of civilization.

Another defect of our present calendar that is regarded by advoates of the 13-month plan as particularly serious is the fact that the month is not evenly divisible into weeks, so that, in general, the end of the month does not coincide with the end of the week. That this is a defect can hardly be questioned. It may, however, be questioned whether the defect can be overcome without at the same time introducing a still greater defect. If the remedy is worse than the disease, we might well prefer to suffer the disease to continue.

Under our present calendar the year consists of 52 weeks plus 1 day or plus 2 days, depending on whether it is an ordinary year or a leap year. As already pointed out it can be made to contain 52 weeks, with no remainder, by including one 48-hour period under a single day name in each ordinary year, and two such 48-hour periods, each under a single day name in each leap year.

The 52 weeks, or 364 days, may then be divided into months of whatever length is found most convenient. Under a 12-month plan the months can not be of equal length, since 364 is not evenly divisible by 12. The best that can be done is to have 8 months of 30 days each, and 4 months of 31 days each. The most satisfactory arrangement of these months, as already pointed out, is to have each quarter of the year contain one 31-day month, followed by two months of 30 days each. Under this plan the end of the month will coincide with the end of the week only at the end of each quarter; that is, at the end of each 13-week period.

The months can be made equal and at the same time each month made to contain an integral number of weeks, with no remainder, only by dividing the year of 52 weeks into months of 2, 4, 13 or 26 weeks each, since these are the only factors of the number 52. Of these possible divisions, the only one that results in months approximating in length those of our present calendar is that of 13 months of 4 weeks, or 28 days, each.

At first sight this seems like a reasonably satisfactory arrangement, and it no doubt would be if we were accustomed to it. The principal objections to it are (a) that it is too radical a departure from our present calendar to be readily accepted by the public; (b) that 13, being a prime number, can not be divided into sixths, quarters, thirds and halves, as can our present calendar year of 12 months. This would necessitate an extra closing of all books and accounts for business conducted on a quarterly or semi-annual basis, since the

ends of the first, second and third quarters would in no case correspond with the end of a month; (c) for statistical purposes the 28-day month would differ too much from our present calendar months, both in length and in seasonal position, to admit of accurate comparison with our present months; (d) the 13-month calendar would require an extra monthly closing of all accounts, reading of meters, sending out of bills, etc., and would thus add 1/12 to the clerical, postage and other such costs of doing business. (This is in addition to the cost of the extra quarterly and semi-annual closings already referred to.)

What advantages, if any, would accrue to offset these obvious disadvantages of the proposed 13-month calendar? There are two, and only two, that can not be attained equally well under a properly revised 12-month calendar. These are (a) the months would be made equal in length, and (b) the end of each month would coincide with the end of the week; *i.e.*, each month would contain an integral number of complete weeks.

But even these supposed advantages of the 13-month calendar are open to question. Even though all months be made of equal length they will still not be strictly comparable for many statistical purposes because of the number and distribution of holidays and because of seasonal variations. For example, a 28-day month without a holiday can not be said to be directly comparable, for industrial or business purposes, with a 28-day month having one or more holidays or with a 28-day month at some other season of the year. If an equalization, or reduction to the same basis, has to be made, even in the case of 28-day months, what, then, is the advantage of the 28-day month? It is no more difficult to equalize two months of 26 and 25 working days than to equalize two months of 24 and 23 working days, and in those cases in which equalization is not required, comparisons between two months of 26 working days would be as valid and as satisfactory as between months of 24 working days.

In the case of statistics of natural phenomena, such as rainfall, accumulated excess of temperature, etc., there would, of course, be an advantage in having all months of equal length.

Again, is it in reality important that the month be evenly divisible into weeks, so that the end of the month will in all cases coincide with the end of the week? Business may be conducted on a daily, weekly, monthly, quarterly, semi-annual or annual basis. The important consideration is that each unit of time be definite.

The same situation obtains with reference to units of quantity. We purchase some materials by the gallon, others by the cubic foot and still others by the pound. There is no more necessity that the month contain an integral number of weeks than that the cubic foot contain an integral number of gallons.

Employees are usually paid by the day, by the week or by the month, and each employee can usually adjust his financial program in such a way that income and outgo are properly balanced. Such difficulties as occur usually arise from the fact that the income is inadequate in amount rather than from the fact that the period of income is not exactly synchronized with the period of expenditure. In fact, it would appear that these two periods could be completely and exactly synchronized only by putting each individual, firm and corporation on a financial schedule similar to that of the average small boy, who, when he gets a nickel, spends a nickel; when he gets a dime, spends a dime; and when he gets a dollar, spends

a dollar. The general adoption of such a schedule would no doubt bring the period of earning and the period of spending into complete harmony, but, surely, making the end of the month coincide with the end of the week would have no marked influence in the matter. We should still continue to receive our income by the day, week, month, quarter or year, and to spend it in a manner highly irregular both as to amount and as to period of time.

Advocates of the 13-month plan of revision emphasize the importance of the 4-week period as a time unit for business purposes. If the 4-week period does, in fact, possess the advantages claimed for it, there would seem to be no reason why it should not be used for that purpose, by those who prefer it, without in any way interfering with the use of the 12-month, equal quarters calendar for other purposes or for all purposes, by those who prefer it.

Summary

The Gregorian calendar is susceptible of improvement in the following respects:

(1) All years can be made to begin on the same day of the week. This can be accomplished equally well under a 12-month or a 13-month plan.

(2) A slightly more accurate leap-year rule than that now in use can be adopted if desired. There is some doubt as to the need for a more exact rule. If adopted it would apply equally well to a 12-month or to a 13-month plan.

(3) Under a 12-month plan the quarters of the year can be made equal by a slight adjustment of the lengths of certain months of the Gregorian calendar.

(4) The months can be made equal for many industrial purposes, and corresponding months can be made equal and comparable for all purposes, under a 12-month, equal quarters plan.

(5) All months can be made equal by the adoption of a 13-month plan.

(6) Each month can be made to contain an integral number of weeks by the adoption of a 13-month plan.

(7) The date of Easter and other movable church festivals can be fixed equally well under a 12-month or a 13-month plan of revision.

(8) The 4-week period can be used for business purposes, by those who prefer it, without interfering with the 12-month calendar.

FOUNDATIONS OF THE FACE

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I

It is said, "There is no art to find the mind's construction in the face." It is true, the visible evidence of surging emotions and desires may be concealed and the intensity of dominant motives temporarily modified. But, speaking in terms of evolution, bodily and mental constructions are different aspects of the same vital process. For man may surely, though dimly, see in his own face the constructive results of the ruling motives and desires of a long line of animal ancestors, modified by the urgings and prohibitions of environmental influences. And if he so desires, he may find in the features of all his fellow creatures something of the history of their combined physical and mental achievements.

The face is a fortified and a highly discriminating portal to internal privacy. There the chief inspectors and appraisers of vital commodities are assembled, and their structure and behavior is the surest indication of the dominant purpose of the whole complex of bodily and mental activities that we call life. On the other hand, the superb art and the constancy of purpose that is so manifest in the construction and behavior of all living things, in their perpetuation and in their development, individually and socially, is the only clue we have to the "construction of the mind" in either man or nature.

Practically all plants and animals are "made" in unlike pairs, called males and females. This structural dimorphism, called sex, is the outward indication of many complementary functions for the evident purpose of reproduction, and for providing the renewed life with adequate rations, guidance and opportunities for further life and growth. These internal reproductive faculties are supplemented by a great variety of external agencies that have their origin in cosmic, terrestrial and social environments.

Non-living things, such as water, crystals, suns and stars, never have this cooperative sexual duality, nor the ability to reproduce and provide for themselves. They arise intermittently, or *de novo*, from more universal reproductive agencies.

The great community of plant and animal life has grown up slowly, but continuously, within the nutrient shelter of its mother earth, itself the offspring of fertile cosmic agencies. And throughout the geologic ages, all this life has necessarily grown up in essential conformity with the opportunities, the limitations and the demands of its native residence.

In a similar way, every individual plant or animal now grows up from an egg or germ, within the shelter of parental envelopes of some sort, and by means of the nourishment and guidance, bodily and mentally, prepared for it beforehand by its forebears. In other words, all parents and all offspring, dead or alive, constitute one self-provisioning and self-perpetuating organism.

The long sequence of divergent, hesitating steps in the evolution of life is evidently the responses of life to structural and functional innovations of different creative value. In accordance with their potential value, they become

relatively fixed or permanent, and so lay the foundations for further adventures in the art of living. All such innovations come from no one time or place, but from a measureless blue of latent potentialities. They apparently produce the more pronounced fluctuations, or mutations, in the rate, the direction and the fruitfulness of evolution, which in perspective mark the gaps, great and small, in our knowledge of life. Thus our disjointed classifications of natural phenomena, our rigid formulas, graphs and pictorial diagrams of living animals, are but rows of dots summarily indicative of recognizable currents in an endless ocean of otherwise unexplored activities. Thus our crude biological diagrams are to be regarded as four-dimensional mathematical formulas, rather than pictures of any one living thing.

The familiar terms heredity, natural selection and evolution are so artificially restricted and so befogged with technicalities that their real significance is not duly appreciated.

The implications of these four-dimensional figures of speech are inseparably interwoven with one another. They clearly imply that the more helpful, or useful ways of living, germinally, individually and socially, in some mysterious but ever-insistent way, actually are perpetuated and increased, and that the less helpful, or no longer useful ways, are not. They clearly imply that there is a universal trend, purpose or objective in the lawful activities of nature, a vital purpose which is visibly expressed in the successful operation of a moral and ethical method of self-preservation, growth and evolution. It is the rightness of this method which all of us, consciously or unconsciously, are striving to imitate, and to utilize scientifically and artistically, and for the same purpose.

II. Standard Patterns of Cellular Organization

Cells are basic units of life, definitely standardized in form and action. They are to the biologist what atoms and molecules are to the chemist, or what human beings and their social aggregates are to the statesman.

When multiplying cells form multicellular bodies, such as a jellyfish, a worm or a human being, they are always arranged in relatively fixed structural patterns expressive of the various functions they perform for the common welfare. There are not more than half a dozen basic patterns of this sort, such as spherical, branching, spiral, etc. The bodies of all the higher animals, such as certain worms, insects, crabs, fishes and man, are built on a jointed, bilaterally symmetrical pattern, called the triaxial system. They all start from an initial germ cell planted in a more or less spherical mass of food yolk; they then grow up in three main directions, lineally, transversely and radially, thus forming six-sided bodies with what we call a head end, tail end, dorsal and ventral surfaces, and with symmetrical right and left sides. Hence no two points or cells in such a body are ever exactly alike in respect to age, relative location, structure and opportunity.

This highly standardized method of cell growth produces the maximum diversity of bodily organs; and also the best arrangement of them for the internal business of life and for the adaptive adjustment of the body as a whole to the external world. No other method of self-construction is so pregnant with creative possibilities.

The lower kinds of triaxial animals may consist of a great many body joints, or metameres, most of them with a full complement of the essential organs of life. But this multiplicity of similar functions is unduly extravagant,

or cumbersome, and eventually many local improvements arise which serve the main purpose of life more effectively. That is, certain kinds of organs, nervous, sensory, glandular, motor, etc., develop the more in those places where they can best perform their bodily functions, while others disappear or perhaps take on new functions of a very different nature.

In the higher invertebrates, this type of bodily organization settled down, something like a thousand million years ago, into three different sub-patterns, such as those in insects, crustacea and arachnids. That is, all insects and their offspring are built on one of these patterns, all crustacea, crabs, lobsters, etc., on a little different pattern, and all arachnids, such as spiders, scorpions, etc., on still another. It is by their underlying patterns that we are able to recognize them as such, in all their multitudinous varieties now and in past geologic ages.

The arachnid pattern is the only invertebrate pattern which resembles that of man and all the other backboned animals. This resemblance is shown in many ways, too numerous, too peculiar and too constant to be accidental, or what is vaguely called a "mere parallelism." It is seen in the subdivision of the first sixteen or more body joints into five main groups, each one with approximately the same number of joints, the same kind of sense organs, ganglia, nerves, muscles, cartilages, glands, etc. And all these animals arise from the egg in a similar fashion, and make their appearance in past geologic ages in a duly corresponding sequence. This mutually confirmatory evidence of comparative anatomy, embryology and paleontology, according to all the canons of the biological sciences, clearly indicates that man and all his vertebrate predecessors had their origin in a very ancient arachnoid stock, something like a thousand million years ago, and that the fundamental pattern of bodily organization common to all of them has not changed in any essential respects since that time.

This pattern of bodily organization is unique. But like other "types" of living things, it is a chequered, fixed and fluid pattern that periodically appears and disappears, that adjusts and readjusts itself to changing environments, yet still remains the same old pattern.

The advantages of the triaxial method of growth over any branching, spherical or spiral method are obvious. But in what respect the arachnid pattern is any better than that of mollusks, insects or crustacea is not at all evident. Nevertheless, it is clearly evident, I believe, that on that particular foundation all the elaborate structure of fishes, reptiles and mammals have been progressively upbuilt, and that in it are resident the tremendous potentialities of human life.

According to this view, therefore, the first sixteen or more body joints of the arachnids eventually united to form the head and face of man and other vertebrates. The "head," in this technical sense, is the most complex structure known to the biologist. During the last hundred years, or more, innumerable attempts have been made to analyze and interpret its various parts, but all of them have ended in barren and apparently hopeless controversy. Now that we have definite assurance of the kind of animals from which the vertebrates arose, a master key to all such problems is available.

III. Foundations of the Backbone and the Skull

In body building, a good roof and a firm central axis are primary requisites. A skull to protect the brain, and a jointed backbone to enclose the spinal cord and give rigidity and flexibility to the body as a whole, fulfil these require-

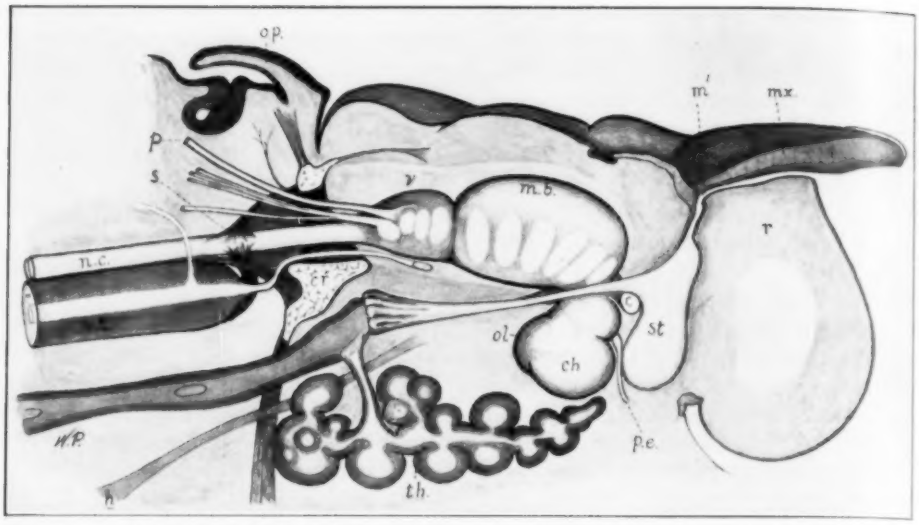


FIG. 1. MEDIAN SECTION OF A LARGE JAVANESE SCORPION (HETEROMETRUS CYANEA)

SHOWING THE FOUNDATIONS OF VARIOUS ORGANS IN THE HEAD AND FACE OF MAN. THE SKULL, OR ENDOCRANIUM, *cr;* THYROID GLAND, *th;* AND STOUT FIBROUS BANDS, *s*, BY WHICH THE NOTOCHORD, *nt*, IS FIRMLY ATTACHED TO THE FLOOR OF THE ENDOCRANIUM.

ments in all the higher animals from fishes to man, and provide the framework for the more elaborate details of the head and face.

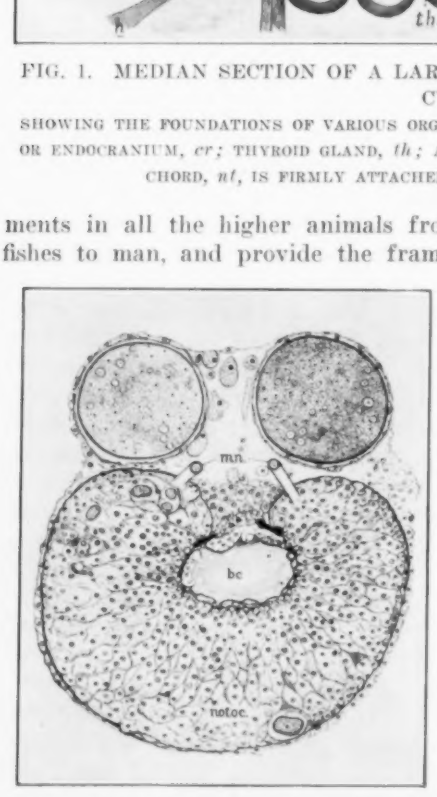


FIG. 2. THE FOUNDATIONS OF MAN'S BACKBONE.

THE NOTOCHORD OF A JAVANESE SCORPION IN CROSS SECTION. BLOOD CHAMBER, *bc;* MEDIAN NERVE, *mn*, ROOTED AT INTERVALS IN THE NOTOCHORD, AND IN THE GANGLIA OF THE CORD.

But the backbone is always upbuilt, embryologically, around an unjointed rod called the notochord, which is evidently a far more fundamental structure than the backbone itself. And so the notochord and the primitive cranium have been the themes of endless investigations and speculations as to their methods of development, their initial functions and the kind of animals in which they arose.

In spite of all these investigations, no worm, insect, crustacean or any other invertebrate shows any traces of the presence of both of these structures at the same time, except the arachnoids. There, as shown in a median section of a large Javanese scorpion (Fig. 1), both of them are present in their characteristic forms and relations, together with very definite evidence of their initial functions. From such evidence, it is clear that our skull was, primarily, a cartilaginous framework for the attach-

ment of powerful muscles which moved, hingelike, the primitive head (cephalothorax) on the body.

The notochord was a cylindrical rod, containing a median nerve and a blood channel, heavily invested with lymphoid supporting tissues (Fig. 2). This primitive ridgepole of our body was stiffened, in the early vertebrates, with many cartilaginous hoops and props which eventually united and changed into bony vertebrae (Fig. 3). Within them are now enclosed the spinal cord, together with the last remnants of the notochord and the median nerve of our arachnoid ancestors (Fig. 3).

IV. The Old Mouth and the New

In all the invertebrates, such as worms, insects and scorpions, the mouth is the external opening of a very ancient passage way (stomodaeum) through the floor of the brain into the main alimentary canal.

Here, the architect of our destiny seems to have blundered in locating the front door of the body in such an inconvenient place. At any rate, the increase in the volume of the forebrain region, which inevitably accompanies the higher stages of life, tends to constrict this ancient gateway to the gut, and thus to cut down the influx of nutritive materials. For that reason, many of the invertebrates, and especially the arachnoids, are obliged to live on a liquid diet sucked through a pinhole corridor in the floor of an overgrown brain (Fig. 1).

In this scorpion, for example, the mouth is a minute pore, m′, completely covered up by rigid spurs or maxillaria. But on the under side of the spurs, on the fourth pair of legs, is an elaborate network of capillary canals through which the juices of their prey were slowly pumped into the mouth and through the floor of the brain into the main alimentary canal.

This was a serious administrative problem for our scorpion-like ancestors. For the bigger their brains, the less they could eat. Moreover, all the tendencies of bodily growth seemed to conspire for the closing up of this opening. Apparently there was but one way out of this impasse in the evolution of two equally essential functions. And, strangely enough, that way was already prepared in the form of an obscure opening into the gut on the opposite side of the head, called the dorsal organ, or cephalic navel (Fig. 9A).

This opening offered an opportunity for a more direct and unobstructed passageway into the alimentary canal, and eventually it became the mouth of man and of all the other vertebrates.

This old trapdoor through the floor of the brain (infundibulum) still remains as a conspicuous cerebral landmark which has long been known to the surveyors of vertebrate brains. But its

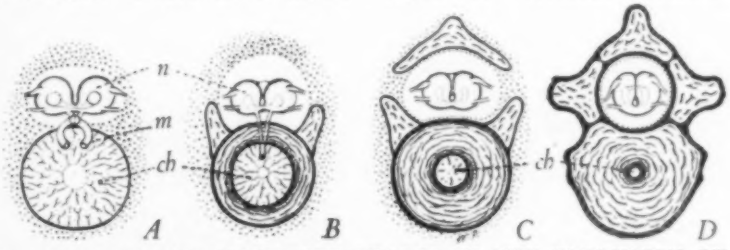


FIG. 3. DIAGRAMS OF SUCCESSIVE STAGES IN THE EVOLUTION OF THE BACKBONE.

Scorpion, *A*. Fishlike vertebrates, *B,C;* man, *D*. Notochord, *ch;* median nerve, *m n;* spinal cord, *n*.

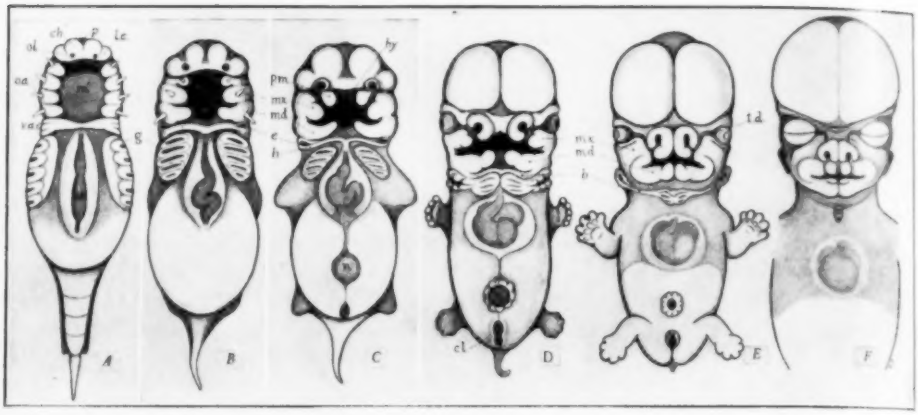


FIG. 4. DIAGRAMS OF VARIOUS STAGES IN THE EMBRYONIC DEVELOPMENT AND THE EVOLUTION OF THE BODY AND THE FACE,

FROM THE ARACHNIDS, *A*, TO MAN, *D,E,F*. STAGES *B* AND *C* ARE LARGELY HYPOTHETICAL, BUT THEY ARE BASED ON KNOWN CONDITIONS IN FISH-LIKE VERTEBRATES, AND ON THE ARRANGEMENT OF ORAL ARCHES IN THE OSTRACODERMS. *e*, EAR; *ch*, CEREBRAL HEMISPHERES; *cl*, CLOACA; *g*, GILLS; *h*, HYOID ARCH; *ht*, HEART; *hy*, HYPOPHYSIS; *md*, MANDIBLE; *mx*, MAXILLAE; *n*, NAVEL; *p.mx*, PREMAXILLAE; *t.d.*, TEAR DUCT; *v.a.*, VAGUS, AUDITORY AND HINGING METAMERES.

origin and its significance was unrecognized. In man, it is entombed by overhanging cliffs of bone, and overgrown by forests of tangled tissues. But there it stands, reproduced generation after generation, as one of those living ruins of primordial life which man so unwittingly carries about with himself (Fig. 9).

The formation of a new mouth, probably in the Cambrian or some Precambrian era, was one of the most fruitful and dramatic events in the history of organic evolution. It revolutionized all the existing functions of life and gave rise to the greatest variety of aberrant forms ever produced in any one geologic era. It also laid the corner-stone for the longest sequence of evolutionary stages, from class to class, known to the biologist.

It was, therefore, a structural innovation of supreme functional value. Like all such innovations, it temporarily accelerated the rate and diversified the products of evolution. It inevitably produced one of those great mutations or, in perspective, one of those apparent gaps in the march of evolutionary processes, which are always so baffling to the biological historian. And the great variety of new kinds of animals which so suddenly appeared on the horizon, many of them crippled and degenerate, or imperfectly adjusted to the new conditions of life, greatly added to his confusion.

V. The New Face and the Oral Arches

The formation of a new mouth and the convergence around it of six pairs of oral arches marks the beginning of a new fashion in faces. The series of diagrams in Figs. 4 and 9 will help us to visualize some of the stages in the evolution of these modern faces, starting with the fashion in scorpions and fishes, and leading up to the most modern fashion in man. Every bodily organ is involved in these changes, but the fundamental pattern of bodily organization remains essentially the same.

The principal events here illustrated are the progressive transformation of the jaws, gills, brain and heart; and

that of the great cephalic sense organs, visual, olfactory and auditory. The larynx, the main instrument of articulate speech, is eventually formed from remnants of the old gill arches. The march of these events is dominated by the great volume and the precocious development of the brain and the heart and by that of the nutritive and excretory systems. Their priority is expressive of some of the more fundamental requirements of bodily developments.

There are several notable centers of construction toward which certain groups of organs and their tributaries converge and eventually unite; namely, the mouth, the larynx, the heart, the belly button, and the cloaca, or the main outlet of the genital, urinary and alimentary organs.

The principal stages in the evolution of the face from fishes to man are well known to the biologist, but no adult stages between fishes and their invertebrate ancestors have been found. We have now discovered, I believe, conclusive evidence of this sort in an obscure group of extinct animals called the Ostracoderms. Their fossilized remains are very rare and always fragmentary, but it is quite certain that once upon a time, long before the true fishes came into existence, they formed a large and highly diversified class of animals, different in many important respects from any other class.

We maintained, more than forty years ago, that the Ostracoderms were the "connecting link" between the vertebrates and certain arachnoid animals, such as the giant sea scorpions, which in the days of their prime were the highest animals in existence and the so-called "rulers of the seas." The new specimens of Ostracoderms confirm this interpretation. Some of them were obtained on my last expedition to the Island of Oesel in the Baltic Sea. A brief report appeared in the *Dartmouth Alumni Magazine*, June, 1931, and in *Science* for June 19, 1931; and some of the specimens were exhibited at the New Orleans meeting of the American Association, in January, 1932, and at the New York meeting of the Anatomists in April, 1932. A full description of them will appear later.

The Ostracoderms are of special importance, in that they show us some of the most significant stages in the construction of modern faces. They illustrate what may be regarded as tentative trial adjustments of the oral arches, jaws or gnathites, around the new

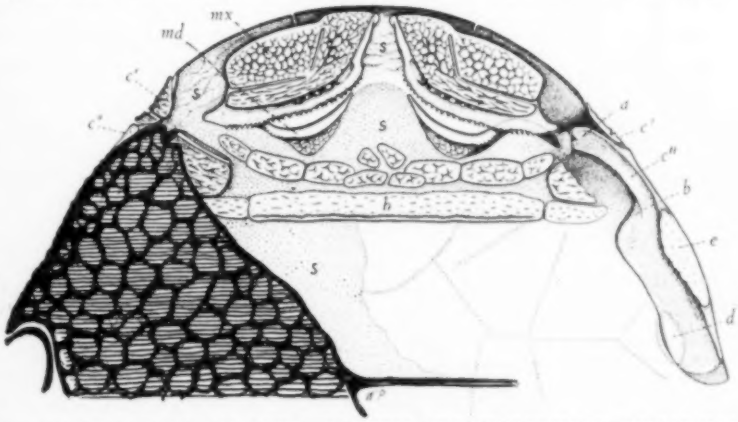


FIG. 5. THE FACE OF AN OSTRACODERM (BOTHRIOLEPIS) FROM CANADA UPPER DEVONIAN. RIGHT SIDE PARTLY REMOVED. *h*, HYOID ARCH; *md*, MANDIBLES; *mx*, MAXILLAE; *c'*,*c''*, CHEEK PLATES; *s*, SKIN.

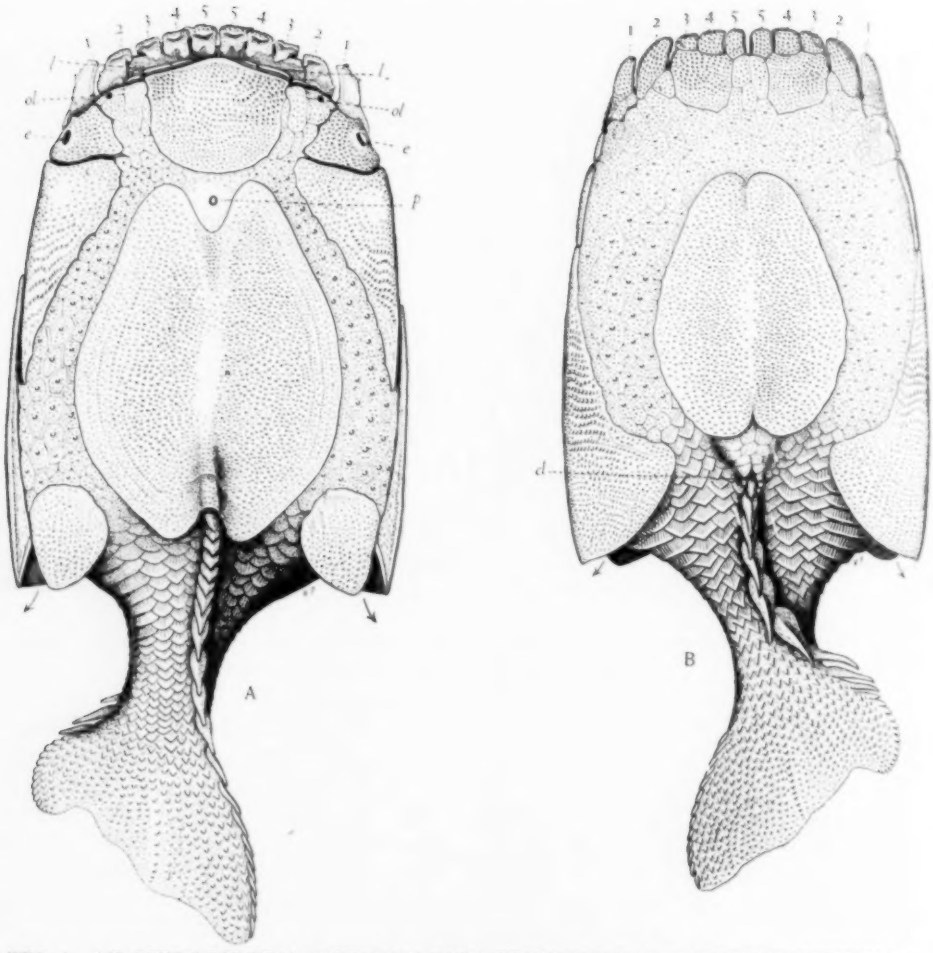


FIG. 6. AN OSTRACODERM (DREPANASPIS) FROM GERMANY; MIDDLE DEVONIAN. *A*, DORSAL SIDE; *B*, VENTRAL SIDE; *cl*, CLOACA; *e*, LATERAL EYE; *l*, LABIALS; *ol*, OLFACTORY PIT; *p*, PINEAL; 1–5, ORAL ARCHES, OR GNATHITES.

mouth, before they finally settled down into the standard facial combinations so characteristic of the higher vertebrates. At least three kinds of Ostracoderm faces are now known. They all look extremely grotesque, for externally they are indeed very different from any animals with which we are familiar.

In one type (Drepanaspis) from the lower Devonian of Gemünden am Rhein, four or five pairs of jaw-like oral arches are present (Fig. 6). They are covered with bony plates and project forwards, beyond the upper side of the head, to form a stiff lower "lip" to an enormous scoop-shaped mouth. Each of the four central arches ends in a rounded dental cusp. It is certainly a very poor kind of face, but these animals managed, nevertheless, to make a living with it by scooping up starfishes and other similar animals from the bottom of the sea, as is clearly shown by their fossilized excrements, which are spiral clumps of calcareous spines.

The second type (Bothriolepis, from

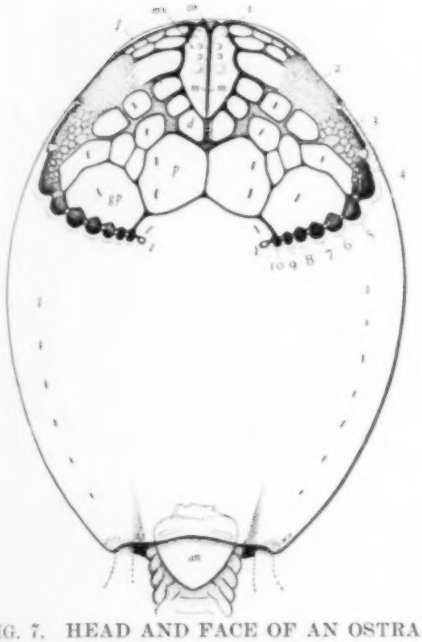


FIG. 7. HEAD AND FACE OF AN OSTRACODERM (TREMATASPIS SCHMIDTI)

FROM THE ISLAND OF OESEL. SILURIAN. *co*, ORAL CUSHION; *g.p*, GILL PLATE; *l*, RAISED MARGIN; *m*, SLIT-LIKE MOUTH; 1–10 SEGMENTAL INCISIONS IN THE SHELL-LIKE COVERING.

the upper Devonian of Canada) is more like the standard condition seen in true vertebrates (Fig. 5), that is, the oral arches lie in a transverse direction instead of a longitudinal one. Here, as I first described many years ago, there are four rows of plates, probably representing various parts of four pairs of oral arches. One represents the maxillary arch and another the lower jaw. But they have not grown together across the median line, as in all true vertebrates. Hence these animals have to chew their food sidewise, and by other very complicated facial movements. The folds of skin, s, between the crushing edges of the maxillae, and between the points of the mandibles, clearly indicate the way they act and the location of the mouth.

They usually live in shallow inland waters and feed on soft fern-like water plants, as shown by the purely carbonaceous contents of their stomach, or intestines. The so-called "operculum," c, is not a movable gill cover, for it is firmly locked on three sides by stout overlapping sutures and internal processes, a, b, c, d. The gills lie behind the auditory vesicles and open with the cloaca into a common peribranchial chamber. Hence the great swimming arms are certainly not pectorals, but probably true cephalic appendages, like those of the giant sea scorpions.

The third type is represented by Trematapis, and other Cephalaspids, from the Island of Oesel. Trematapis lived in the Silurian age. It is one of the oldest of all the Ostracoderms and therefore has special significance for us. Its remains are very fragmentary, and heretofore only a very few imperfectly preserved specimens have been found.

The specimens obtained on my last expedition clearly show that Trematas-

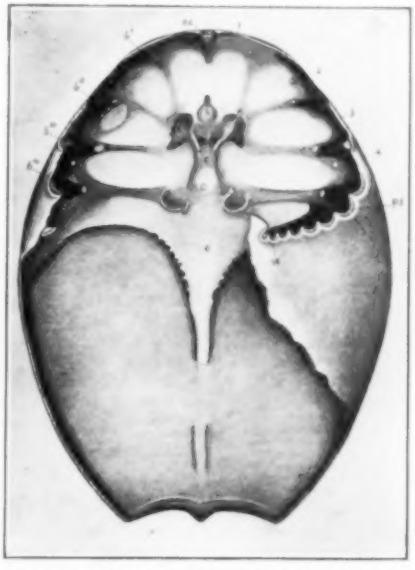


FIG. 8. HEAD OF TREMATASPIS.

THE ORAL PLATES HAVE BEEN REMOVED, SHOWING THE BROAD, FLATTENED FLOOR OF THE CRANIUM, *c*; PARTS OF THE EAR, *e*; THE OLFACTORY-HYPOPHYSEAL TUBE, *h*; LATERAL EYES, *a*; THE ENDS OF FOUR ORAL ARCH BARS, *b*, 1–4; AND THE POST BRANCHIAL SEPTUM, *p.s.*

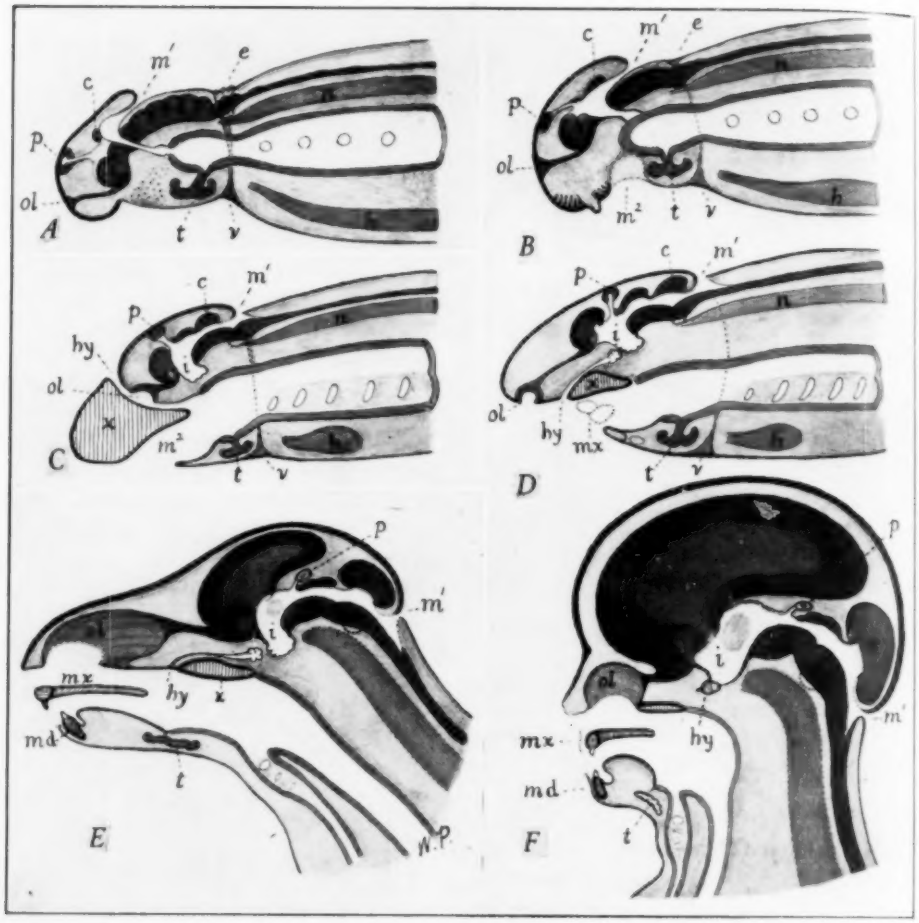


FIG. 9. DIAGRAMS, IN LONGITUDINAL SECTION, SHOWING THE FOUNDATIONS OF SOME OF THE IMPORTANT ORGANS OF THE HEAD AND FACE

FROM SCORPION-LIKE ANIMALS, *A* & *B*; PRIMITIVE FISHES, *C* & *D*, AND MAMMALS, *E*, TO MAN, *F*. *c*, CEREBRAL HEMISPHERES; *e*, EAR; *hy*, HYPOPHYSIS; *i*, INFUNDIBULUM; *m′*, PRIMITIVE MOUTH; *m″*, NEW MOUTH; *mx*, MAXILLAE; *md*, MANDIBLES; *n*, NOTOCHORD; *ol*, OLFACTORY ORGAN; *p*, PINEAL EYE; *t*, THYROID; *v*, VAGUS AND PRECARDIAC SEPTUM; *x*, PRE-OLFACTORY ROSTRUM AND ETHMOIDAL CUSHION.

pis, in the adult stages, has at least four pairs of preotic and prebranchial oral arches, covered with bony plates (Fig. 7). The mouth is a median longitudinal slit flanked by heavy jaw-like structures, which in chewing worked transversely, not forwards and backwards, as in typical vertebrates.

When these covering plates are removed, the various parts of four distinct preotic and prebranchial metameres are revealed, including bony spurs for the attachment of oral arch muscles, various openings for blood vessels and nerves, and shallow grooves for corresponding gut lobes (Fig. 8).

It now appears, from the above evidence, and other evidence that we can not go into here, that six pairs of thoracic arches of the arachnoid type

were involved in laying the foundations of our face. The first one or two pairs, carrying with them the adjacent olfactory placodes and other tissues of a glandular nature, first united at the very anterior end of the head to form the infolded roof of the mouth (Figs. 6 and 9, A, B, C). It may well be that the olfactory-hypophysial canal, by, thus formed in primitive Ostracoderms and in the Cyclostomes, served as a makeshift mouth, while the other arches, premaxillae, maxillae, mandibles and hyoids, were assuming in a somewhat similar manner their final arrangements.

Meantime it is significant that the made-over remnants of the oldest recognizable structures in this long series of animals were assuming the extraordinary functions of regulating the multitudinous activities of the body as a whole. These very ancient organs in their new disguise are the so-called ductless glands. The structural foundations of them, especially the pineal gland, the pituitary complex and the thyroid, were laid down with those of the head and face in our arachnoid ancestors, and they now play a conspicuous rôle in our facial expressions.

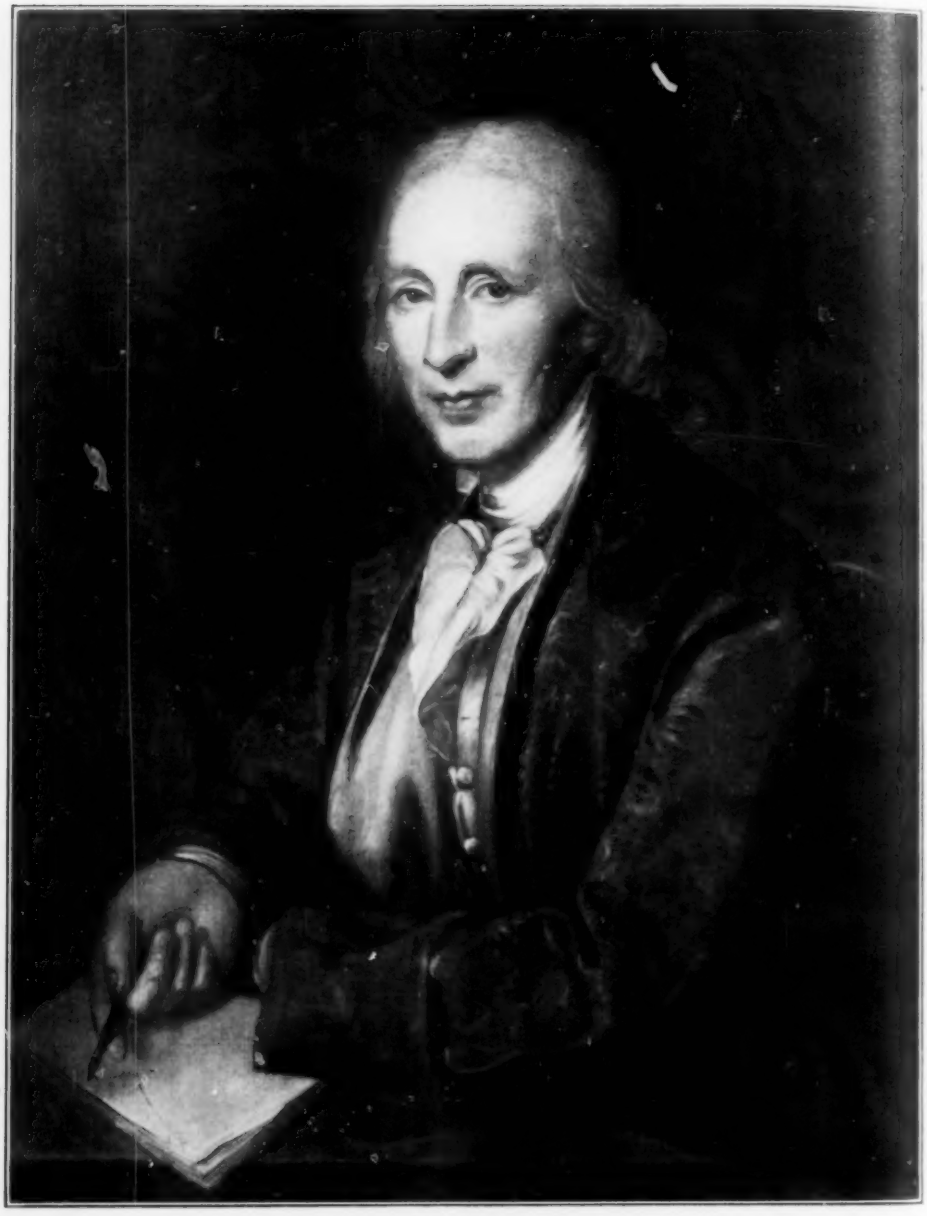
As I have said in the *Dartmouth Alumni Magazine:*

> All this is not merely a new bit of evidence for evolution. It will require new interpretations of many anatomical and embryological data, and far reaching readjustments of our philosophy of evolution. We biologists are commonly content to point out this or that path which evolution has taken in the past, or may take in the future, but we have very vague ideas as to the relative values of the parts played by heredity, by environments, and by individual organisms.
>
> But here, it seems to me, we have the most impressive picture of the creative power of a specifically constructed organism that science gives us. For this initial pattern of bodily structures and functions dominates the whole sequence of evolutionary processes from sea scorpions to man. Environments, heredity, and natural selection are essential to the realization of its inherent potentialities, it is true, but they have made no radical changes in the pattern itself, for something like a thousand million years.
>
> There is no other known sequence of natural phenomena so vast, so complex, and so precisely determined in its inception, in the course it follows, and in the fertility of its results. Mankind has grown up out of this scorpion-like germ from an immeasurable past, with the same marvellous precision that to-day a new human being grows up from a specially constructed egg or germ cell. To the biologist who really sees and feels these things, the age of miracles—real honest-to-god miracles—has not passed away.

And so it should not be forgotten that all evolutionary phenomena are fundamentally inexplicable. Atoms and protoplasmic cells, wavelets and bullets of energy, kingdoms and principalities of plant and animal life, by themselves alone have no significance, and no measurements, comparisons, or enumeration of them will give us any real explanation of their origin or their magic performances. We see all these mysterious rabbits come out of a magic hat. That is all. The sequence, and the source, are the only clues to understanding.

The most significant discovery of modern science is that this furious mob of heterogeneous agencies, in some wholly unimaginable way, really does flow methodically and imperturbably in the mutually self-perpetuating ways of life and evolution.

The amazing performance proceeds, openly and regularly, yet no one can see how the trick is done. But we suspect there is some sort of collusion between the Magic Hat and all these goddam rabbits.



DAVID RITTENHOUSE

THE LILY PORTRAIT, BY CHARLES WILSON PEALE, PAINTED FOR THE AMERICAN PHILOSOPHICAL SOCIETY, SO CALLED BECAUSE OF THE LILY-LIKE RUFFLE UNDER HIS STOCK.

THE DAVID RITTENHOUSE BICENTENARY

By Dr. M. J. BABB

DEPARTMENT OF MATHEMATICS, UNIVERSITY OF PENNSYLVANIA

THE Ancient Greeks had three problems which they were unable to solve with their specified tools—the compass and the straight edge. Modern mathematics has shown that they might have limited themselves to one or the other tool. The three problems were: to find the area of a circle, to duplicate a cube and to trisect an angle. The whole of Greek geometry was invented as a by-product without accomplishing the solution of any of these problems, and modern mathematics has shown that all three are impossible with the implements specified, though every year solutions are promised by men otherwise honest and honorable, the last one of these fallacies having been issued within a year by the head of a recognized school of a great church.

Modern mathematics also has many problems. I will mention three of them; the first one you may play with at your leisure. If you were drawing a map of Europe or the United States or the counties of a state or the township of a county how many colors would you have to use in order to make the boundaries distinct? Would four do, or can it be done with less? A second; we know three squared plus four squared equals five squared. Do any other like powers of two different integers sum to the same power of another integer? The other problem I want to mention is the so-called three-body problem and its extension, the n body problem, namely, having written out the equations of the motions of the sun, earth and moon, do these equations assure us of permanency except for slight self-correcting fluctuations? Eddington in his latest book comes to the conclusion that the universe is running down—that some day these planets and their satellites will revolve no more among that great galaxy of stars that God hath wrought. It is not a happy thought, even though we rejoice in the spirit and the joy of effort.

David Rittenhouse, living some twenty miles from Philadelphia, near the nineteenth milestone on the Reading Pike and four miles from what is now called Norristown, having already constructed clocks that surpassed in their accuracy those made in this country and abroad, conceived the brilliant idea of making a machine to simulate the motions of the planets, Mercury, Venus, Earth, Mars, Jupiter and Saturn, with their then known satellites. Comparing the tables then calculated and making many computations of his own he set up a machine which was so accurately devised that when you set the hands on the dials to any time five thousand years before or after 1770 you can with a small telescope make accurate observations of the places of these bodies in the heavens, just as if you had lived in that time long ago or long to be. Had there been an ancient Egyptian—even before the days of Ahmes the Moon Born, who wrote the "Explanation of All Dark Things," the earliest known mathematical book—who should wake up from some mummified body and remember that he had forgotten a priestly observation, he could rectify his laxity by turning these mimic orbs by means of a crank back till the hands pointed out the time, not to the nearest century or month but to the very day, hour and instant of his lapse. Then he could turn them forward and find out what horoscope

DAVID RITTENHOUSE

PROFILE OF BUST BY THE CELEBRATED CERACCHI WHILE IN AMERICA. NOTE THE EXPRESSION OF PAIN SEEN ONLY IN THIS VIEW OF THE HEAD.

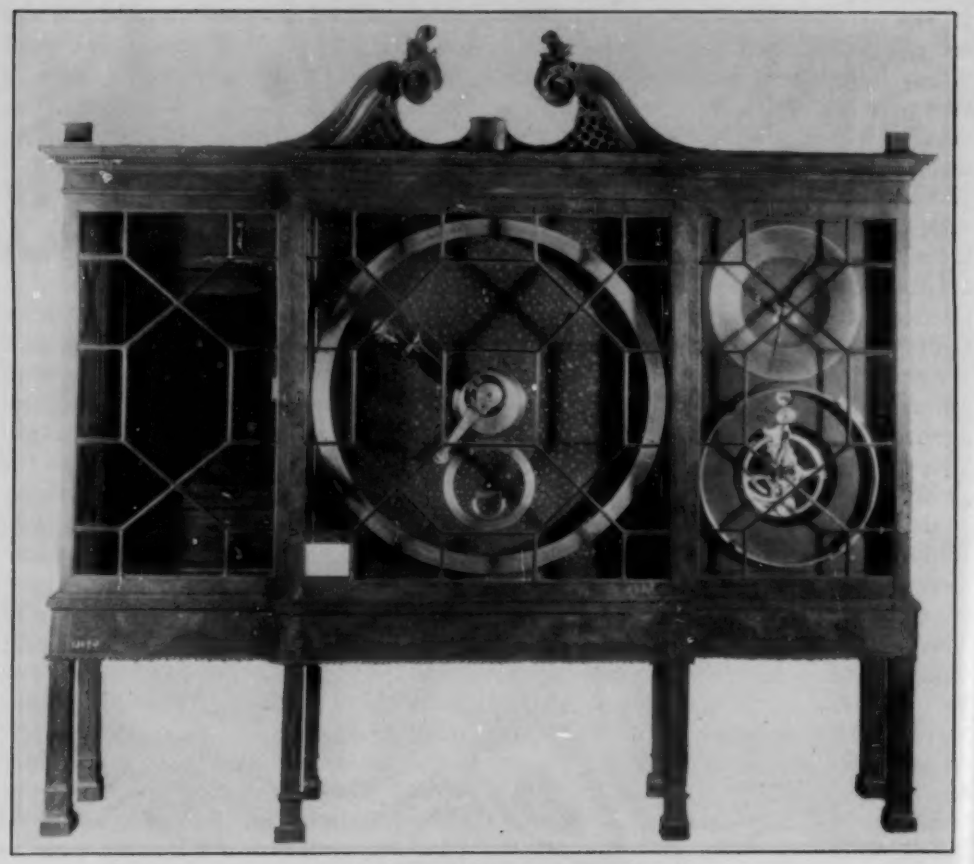
James Logan sent William Penn when the latter's son was born, and we could compare it with what we know of that young rascal who so foolishly sold the land that nourished David Rittenhouse. By it we could tell whether it was moonlight when Anthony walked with Cleopatra, or Abélard with Héloïse.

To the right of this central face is a lunarium, which will give the positions of the moon during the ten thousand years that this instrument is accurate.

It will tell the time, duration and character, whether total, partial or annular, of any eclipse of the sun or moon during that period and moreover will point out accurately the place upon the earth at which particular eclipses of the sun are visible. The Austrian mathematician and astronomer, Oppolzer, has made a table of all the eclipses during historical times; one of these stopped a great pitched battle between the Medes and Lydians on the 28th of May, 585 B. C. We can turn a crank and check all these eclipses and list all that are to come during the next five thousand years. This instrument is so in tune with the great handiwork of God that there is no doubt in the hearts of any of us that Eddington's awful prediction can not come within any time appreciable by us or ours. Men like Adams, Jefferson, Washington and others recognized the exquisite mechanics of Rittenhouse in making this image of the heavens above, though others professed to believe him an atheist, a mocker of God and a man of evil.

Let us use the Orrery, as it was called, in turning back over the life of Rittenhouse and his progenitors. We will find that, though we can reproduce the motions of the planets, the so-called fixed stars were beyond his ken and many of the comets were visitors from the unknown and that Rittenhouse has not even attempted to reproduce the motions of those captured by Great Jupiter. Though we can accurately trace the path of an eclipse upon the surface of the earth its hundred miles of breadth is here but a fine line, and there would be no glass powerful enough to pick out the people if they could repopulate the earth as they did in those long past days. As we turn the wheels of the Orrery, repeating again the position of the planets they saw, we will have to use the two eyes of history and tradition, each of which may tend to clear the vision and complement the view of the other. Let me illustrate: In that great first story of man and his creation, a woman came into the life of man, so biblical history tells us, though most of the beauty and grace of the tale has been lost in the torrential threats of hell and damnation that invariably accompanied its telling. But there is a tradition that down in the bottom of our hearts we firmly believe to be true. It is that that woman alone with that man, as no woman has been alone with any man since, feared repetition, and further tradition tells us that it was she who would first awake from sleep in the dawn of that creation and feverishly count the ribs of her mate in an ecstasy of fear and jealousy, and thus began that which we now call Arithmetic.

So I shall endeavor with the eyes of history and tradition to go back to the year 1644 when Isaac Newton was two years old, when England was still in the reign of Charles the First, having just begun to sense the reverberations of the Thirty Years War, that destroyed one in every three in Germany, and bled white the other two. In that year in England was born William Penn, the founder of Pennsylvania, and in Germany Willem Rüttinghüysen, papermaker of the Ruhr, who would set up the first papermill in Penn's green woods. In England the first born inherits the land and title, while the younger children take up the army or the priesthood or teaching or some other respectable but impoverished vocation. Admiral Penn, the young husband of a Dutch wife, saw that England would not cling to this king, yet thought still he could fight for England against her enemies without, until the family quarrel was settled. Though the first controversy with Charles was over ship money, England's navy took no part whatever in the civil war, so when sent to the West Indies on his own and his



THE RITTENHOUSE ORRERY

AT PRESENT LOANED BY THE UNIVERSITY OF PENNSYLVANIA TO THE FRANKLIN INSTITUTE, WHERE IT HAS BEEN BEAUTIFULLY RESTORED FOR USE WITH THEIR NEW ZEISS PLANETARIUM. THE CENTRAL FACE IS A PLANETARIUM; THE LONG ARM CONTAINS SATURN, HIS RING AND SATELLITES, THE SHORTER BRASS ARM JUPITER AND HIS SATELLITES, WHILE WITHIN ARE MARS, EARTH, VENUS AND MERCURY. THE LARGE CENTRAL BALL REPRESENTS THE SUN. THE SUN AND EARTH CAN BE REMOVED AND A SMALL TELESCOPE REPLACE THEM, WHICH WILL READ THE POSITIONS OF THE OTHER PLANETS THROUGH MARKINGS ON THE LARGE CIRCLE WHOSE INNER HALF MOVES AND REPRESENTS THE ECLIPTIC. THE HANDS FOR SETTING THE TIME 5000 YEARS BEFORE OR AFTER ARE IN SMALL CIRCLES BELOW. THE LUNARIUM IS ON THE RIGHT. THE DAYS OF FOUR CONSECUTIVE YEARS ARE ARRANGED IN A SPIRAL THREE DEEP. AND THE CENTURY YEAR, MONTHS AND DAY CAN BE VERY ACCURATELY SET IN THE UPPER PART. BELOW A CYLINDRICAL ARRANGEMENT IS DIVIDED IN 360 SQUARES REPRESENTING FIVE DEGREES OF NORTH AND SOUTH DECLINATION AND 360 DEGREES OF AZIMUTH. THE EARTH IS STATIONARY EXCEPT FOR DAILY ROTATION AND CHANGE OF AXIS, AND IS SITUATED IN THE SMALL CIRCLE AT THE VERY TOP OF THE LOWER FIGURE. A POINTER ATTACHED TO THE VERY COMPLICATED WHEEL WORK IN THE CENTER POINTS OUT ON THE INNER SURFACE OF THIS CYLINDER THE POSITION OF THE MOON. ITS DECLINATION AND RIGHT ASCENSION ARE EASILY READ BY THE OBSERVER LOOKING IN THE EYE-PIECE SHOWN NEAR THE CENTER OF THE WHEEL WORK. THIS HAS A 45 DEGREE MIRROR THROUGH WHICH THE POINTER IS CLEARLY VISIBLE AGAINST THE SILVERED SQUARES ABOVE AND BELOW THE ECLIPTIC. THE CIRCLE UNDER THE EARTH HAS AN HOUR HAND AND FRACTIONS OF HOURS ARE READILY READ. THE WHOLE CYLINDER MOVES SO AS TO KEEP THE EARTH IN ITS PROPER RELATIVE POSITION. OF

country's quarrel, after having fought with his wife's relations, the Dutch, Admiral Penn captured Jamaica. It is said that one of his captains reported to him on the Dutch possessions in America which the admiral ever afterwards looked upon as a means of restoring the younger branch of the Penn family to which he belonged. After the peaceful and spontaneous recall of Charles the Second the admiral sent Captain Holmes over again to take possession of the Dutch colonies on the eve of the last great war with Holland. And in due time, after some weeks in the same tower in which the Penns—father and son—dwelt more than once, Holmes' capture was acknowledged and the New Netherlands and the western bank of the Delaware became the property of the Duke of York, who had agreed to be guardian to young William Penn. The younger Penn cherished the tradition of his father toward this new land, yet having become a Quaker he yearned not for titles but only for a place to establish a green country town and to proclaim a land where all might be free and equal and undisturbed in their religious views. Passing over into Holland, doubtless realizing that the doctrine of "inner light" had been wafted across the Straits from the Rhine and being half Dutch himself he extended a gracious welcome to immigrants from the Lowlands. Francis Daniel Pastorius, a learned and emotional barrister, having just returned from "the grand tour" of Europe with a rich sprig of nobility, heartily answered the message and landed in America soon after the *Welcome*. In Philadelphia he built a little house above a cave and placed on it this inscription: *Parva domus, sed amica bonus procul este proephani*—Small is my house but open to good men and closed to the evil, at which Penn smiled and entered and invited him to dinner every day.

Pastorius, upon the coming of other chosen German Quakers, formed the weaver's village of Germantown, soon to be nicknamed because of its poverty Armentown. Here they lived as friendly Quakers until Pastorius and others brought before the various meetings their anti-slavery petition, saying they were against traffic in "men's bodies." Not receiving a quick and warm response they gradually grew cold to some of the Quaker customs and longed for a preacher of their own.

In Germany, where Willem Ruttinghuysen was born in 1644, it was the custom of the eldest son to remain under the parental roof until the second son became of sufficient age and strength to assist the father. The added earnings at this time enabled the father to set the oldest son up in business or on a farm or give him means to make a pilgrimage. This procedure went on until the youngest son was left to assist the declining years of his parents and finally take over the homestead and the family traditions. Thus it was that Willem Ruttinghuysen, the older son, left the family group at Mülheim and went down into Amsterdam in Holland to take up his trade of papermaker, which his family had somehow acquired from connections with the French Hugenots, for his watermark was also used by Wendelin Rehel of Strasburg and the crown and fleur-de-lis are from the arms of France. Soon after 1685 we

COURSE AN ECLIPSE ONLY OCCURS WHEN THE POINTER, WHICH REPRESENTS THE POSITION OF THE MOON, PASSES DIRECTLY IN FRONT OF THE EARTH, WHICH CAN ONLY HAPPEN WHEN THE POINTER IS NEAR THE ECLIPTIC WHEN IT PASSES THE EARTH AT THE 12 O'CLOCK POSITION. THE PHOTOGRAPH IS IN ECLIPSE POSITION WITH THE HOUR HAND DIRECTLY UNDER THE POINTER. THE LEFT FACE ORIGINALLY CONTAINED JUPITER AND SATURN AND THEIR ATTENDANTS. RITTENHOUSE REMOVED THEM WHEN HERSCHEL ANNOUNCED HIS DISCOVERIES AND NEVER REPLACED THEM.

Sir

Dauph. 26th 1792

D. Smith being very desirous of purchasing the Orrery for the College of Philadelphia, undertook to raise money in his own way to pay for it. He procured several Companies of 8 or 10 persons each to subscribe £5. I think, each Comp. They were to attend Lectures which I was to give on the Orrery. All the money so collected was I believe paid to me. How far it is right for the D. to have credit for this money, when so much of the drudgery of raising it fell upon me, I will not determine. I need not add that nothing is farther from my thoughts than to put in any claim. But D. Smith says, and I believe it to be a true state of the case, that he himself gave a Course of Lectures in Natural Philosophy, during the same winter, and that the money raised by them was also applied towards paying for the Orrery. The whole sum I received was what D. Smith reports. £65. of which was in his presence, and as soon as it came into my hands paid to Parnell Gibbs and John Folwell, Joiners, for the Orrery-Case. So that the remainder £42.10 was all that I have ever received for my labour ——

I am Sir, your humble Servant

Dav. Rittenhouse

Wm. Pettit

A LETTER ABOUT THE ORRERY

THIS LETTER WAS FOUND BY THE AUTHOR AMONG THE PAPERS RELATING TO THE CONFLICT BETWEEN THE OLD COLLEGE OF PHILADELPHIA AND THE NEW UNIVERSITY OF THE STATE OF PENNSYLVANIA BEFORE THEIR UNION. THE CASE OF THE ORRERY IS POSSIBLY OUR MOST MAGNIFICENT PIECE OF COLONIAL CABINET MAKING AND WOOD CARVING, AND ITS AUTHORSHIP WAS UNKNOWN BEFORE THIS LETTER WAS DISCOVERED.

find him setting out for America, possibly because of the influx of seventy thousand French Huguenots into the Rhine Valley and neighboring cities after the revocation of the Edict of Nantes or possibly from an adventurous longing to follow relatives who had settled in New Amsterdam as early as 1641, but most likely called as minister to complete the company of German-

town Mennonites. It is safe to say that he sailed on a Dutch vessel to New York, being warned by the baker Bom and other Crefelters of the poor fare and the danger of being let ashore on the lower Delaware, and other possible ill-treatment from English shipmasters. There likely was a lack of English shipping because of the rebellion leading to the accession of William and Mary. Tradition tells us that he arrived in Pennsylvania with his sons Garet and Claes or Nicholas and his daughter Elizabeth in 1688, and that there was a courtship on the boat, for we find that the bans were read on the 10th day of May and that a marriage takes place in the Dutch Reformed Church in New Amsterdam on the 29th of May, 1689, between this younger son, Claes, late of Arnheim but now of the Lower Delaware, and Willjmintie Dewees of Lieuwardn and now of New Netherlands. Claes brings his bride and her brother William through Jersey, crossing the Delaware near the Falls and passing down near Penn's country seat to join her parents, Garett Hendricks and Zythian, descendants of Jan Pietre (De wees—the orphan), and other members of this family, possibly all originally from Mülheim and former neighbors of the Rittenhouses. This year they seem to have spent in building some sort of habitation in the wild and beautiful but closed glen of the Wissahickon (this valley was closed in by an immense group of rocks at the Ridge Road until 1826).

In 1790 as members of a company formed by Samuel Carpenter, who held the land, William Bradford, the Caxton of America, Robert Turner, old friend of Penn, and Thomas Tress, they erected the first papermill in America on a small branch of the Wissahickon. This labor was accomplished entirely by their own hands without the aid even of barrows, there being no connection with the outside world, except bridle paths to Germantown and boats to Philadelphia. The wheel they first erected was undershot and connected by wooden cogwheel work to the wooden trip hammers that beat up the pulp and smoothed the sized paper obtained from the man-carried waste product of the weavers in Germantown and what rags could be gathered in the city. Richard Frame writes thus in "A Short Description of Pennsilvania or a Relation of What things are Known, Enjoyed and Like to be Discovered in the said Province":

The German-Town of which I spoke before
Which is, at least in length one mile or more,
Where lives High German Peple and Low Dutch,
Whose trade in weaving linen Cloth is much,
There grows the flax, as also you may know,
That from the same they do divide the Tow;
Their trade fits well within this habitation,
We find convenience for their Occasion,
One trade brings in imployment for another,
So that we may suppose each trade a brother;
From linen rags good paper doth derive,
The first trade keeps the second trade alive;
Without the first the second cannot be,
Therefore since these two can so well agree,
Convenience doth appear to place them nigh,
One in Germantown, t'other hard by.
A paper mill near German-Town doth stand,
So that the flax which first springs from the land,
First flax, then yarn, and then they must begin,
To weave the same which they took pains to spin.
Also when on our backs it is well worn,
Some of the same remains ragged and Torn;
Then of the Rags our Paper it is made;
Which in process of time doth waste and fade:
So what comes from the earth, appeareth plain,
The same in Time, returneth to earth again.

Under the caption "Save Your Rags" the following advertisement appeared at a later date in New York:

If the necessary stock is denied paper mills young maids must languish in vain for tender epistles from their respective swains. Bachelors may be reduced to the necessity of personal attendance on the fair.

The paper molds, probably about twenty by thirty inches, were made of

fine screens of reed on the inside of which were placed wires bent in the form designed for a watermark. These molds were dipped into the vat of prepared and beaten pulp which by a quick motion of the hands was spread over the inside surface of the mold. The water from the pulp running through the screen, and the sheet losing much of its moisture, took on the shape of a very wet sheet of paper, the design of the wires laid in the mold caused by their unevenness the watermark. When the skilled papermaker thought the sheet to be sufficiently dry, he turned it out on a kind of blotter which he had placed on the preceding sheet.

In this mill worked at papermaking the older Willem, his two sons and William Dewees, though Garett seems to have soon left and gone to Germantownship. William Dewees in 1710 founded the second paper mill in America, which was in 1713 bought out together with one hundred acres of land by his brother-in-law, Nicholas, William Streepers and John Gorgas, for one hundred and forty-five pounds. The women of the family were kept extremely busy picking and sorting the rags and with other duties about the mill. Willem, the elder, the preacher of the Mennonites in Germantown, became their first bishop. In 1702 a tremendous flood washed away the mill, with all its tools and belongings. William Penn contributed twenty-five pounds and called the elder Willem "old and decrepid," though he was only fifty-eight, the same age as Penn himself. Hard labor and long hours used to make men give up at fifty and sit in a chimney corner for the balance of their lives. The mill was rebuilt and came into the hands of the Rittenhouses alone, who seem to have been prosperous. From June, 1709, to April, 1710, Bradford purchased paper amounting to thirty-six pounds, 13s, 3d. Nicholas made press, writing and brown paper. Here were born the sons of Nicholas and Wilhelmina, William, Henry and Mathias, the latter in 1703, and their daughters, Psyche, Catharine, Mary and Susanna. In 1708 Willem the elder died and was buried in the lot of the old Mennonite meeting house in Germantown; and Nicholas carried on the mill, preached on Sunday and did pastoral work as had his father. The children went to school to Daniel Francis Pastorius at Germantown, whose experience in Philadelphia in whipping the boy Israel Pemberton, later the great Quaker merchant, proved how disastrous it was to cross this famous trader. Finally, after the second William had moved to a farm nearby and his brother Henry to a farm in Worcester Township, Mathias, having remained with his father, took to himself in 1727, the year of Newton's death, a wife, Elizabeth Williams. William Barton, Rittenhouse's nephew, says, "She was a daughter of Evan and Dorothy Williams, Welsh Quakers." Of them I find no record, but it is interesting to note that Susanna, the daughter of the wealthy Jacob Telner, who married Albertus Brant, after his decease married a second husband, one David Williams, about the year 1700. As the name Susanna appears frequently in the Rittenhouse family and Mathias Rittenhouse's wife's brother is named David Williams, there is room for thought. However this may be, Elizabeth Williams seems to have been a woman of "uncommon mind" but with an education "having been much neglected in her youth as is common with orphan children." She seems to have been afraid for the health of her family in the dark valley and at the papermaker's trade and interests her brother-in-law, Henry; they influence Mathias to make a purchase of land from the Norris family, who owned the

manor of Willem Stadt, which Penn had given to his son William and the latter scapegrace had sold almost immediately for pocket money and back debts. It was this Isaac Norris who purchased in London in 1705 for James Logan, Hays fluxions, of which there are two copies in the Loganian Library. In his spare time Mathias seems to have added to the stone house previously built at Norriton, but stayed according to tradition with his father in the new house with the coffin door, and no steps therefrom, that still stands in the park on Lincoln Drive, the only one preserved of the four residences of David Rittenhouse. Here a daughter Esther and a son David, the latter born April 8, 1732, old style, were added to the little family. Eventually in 1734 Nicholas died, and by brotherly agreement the oldest son William took hold of the mill, while the younger family moved to the farm at Norriton, Elizabeth's two younger brothers going with them. At the corner of the farm they found an old Presbyterian Church which had probably been Dutch Reformed in earlier days and whose claim was from "the time whence the mind of man runneth not to the contrary." So to the "said Presbyterian profession" in consideration of "one silver half crown current money of England to them in hand paid," they gave a deed. A few years after they had moved came the great earthquake of December 7, 1737, felt for three hundred miles. It sounded to little David like a great multitude running to and fro in the loft overhead. On September 14, 1735, a warning appeared in the *York County, Virginia, Record:* "It is ordered that it be a standing rule of this court that the Sheriff doth not summon any person to be of the grand jury, who he shall know to be a Drunkard, a common swearer, a Sabbath breaker or Surveyor of the highway, or guilty of any other misdemeanor." Thus, here under the tuition and care of his elder sister Esther, David Rittenhouse began his acquaintance with life, probably going to school in the Presbyterian Church, afterwards and between times taught by his Uncle David, after whom he was named and who had learned the carpenter's trade and been interested in mathematics and possessed a translation of the first book of Newton's Principia. This young man was "delicate" and much at home, so we can imagine with what eagerness the young David listened to the older David about the mystery of mathematics and the use of tools. On bad days they crept up one of the four winding stairs into the great garret and there pored over mathematics and read and reread Poor Richard's Almanac and the *Pennsylvania Gazette,* and talked as boys can and do of their hopes and plans for the future. Young David must have been disappointed when they read in Poor Richard's Almanac when he was six years old the following: "You will excuse me dear reader that I afford you no eclipses of the moon this year. The truth is I do not find they do you any good. When there is one you are apt in observing it to expose yourself too much and too long in the night air whereby great numbers of you catch cold, which was the case last year to my very great concern. However, if you will promise to take more care of yourselves you shall have a fine one to stare at the year after next." In 1743, when David was eleven, he was allowed to stay up late and he and his uncle saw a total eclipse of the moon on October 1st at 10 o'clock in the evening. There was also a figure in Poor Richard's Almanac illustrating the cause of eclipses.

These were stirring times in 1742. Gentle Mathias came home much beaten up from the great election. The great Whitfield had been preaching virtually to thousands. In Philadelphia a build-

ing was erected in 1740 for him to preach in, and Samuel Pennypacker claims this was the beginning of the Academy, afterwards the College of Philadelphia and now the University of Pennsylvania. This was the time when the governor's council denied the right of assembly to appoint other doctors in the place of Dr. Graeme, port physician. The government was in the king and his appointed representatives and was never dissolved. Assumption by the assembly of executive power was a "bare-faced Republican notion."

At Norriton, Hell Fire John Rowland was in charge but was getting, like Cuthbertson, "tired of the ungodly." This was the beginning of the "new lights," the germ of the "rabid whigs," who controlled Philadelphia politics until 1789.

Poor Richard's Almanac of 1744 gives rising and setting of planets "so those who are disposed can learn to distinguish one from the other." That of 1747 promises two total eclipses of the moon, midnight, Feb. 13, and 9 P. M., Aug. 9. In 1748 the Copernican and Ptolemaic systems are explained. Poor Richard compares Ptolemy to a "whimsical cook, who, instead of turning his meat in roasting, should fix that and contrive to have his whole kitchen fire and all whirling continually round it." Mentions Newton's death in 1727 and quotes, "Nature and nature's laws lay hid in night. God said, Let Newton live and all was light."

When David was only twelve years of age Uncle David died and left him his tools and books and he had to carry on the double dreams of the two boys. I would like to give you some of the atmosphere of the times, how they told this sad news to four neighbors and how in the same way it traveled over the countryside, bringing the whole neighborhood to the funeral, how they always knew when neighbor James's sick daughter was going to meeting because her father was out early in the morning smoothing up the long lane with a hoe and rake so she would receive no jar on the journey, how at meeting when the question was put "Has anyone anything to say?" that Lydie Tucker rose and said, "Lewis promised to marry me," but as nobody else said anything the wedding went on. How Aunt Emmy used to sew feverishly when her thread was short, to get through before it ran out. How the weather then was just as peculiar as it is now, though the German historian Ebling says "the dews were often heavy enough to start a dry stream." How after the Quakers withdrew from politics, Philadelphia became strangely neglectful of her own nestlings, seemingly ashamed of even her legitimate children if they began to attract public notice in Philadelphia before becoming known in foreign parts. This incidentally was the time of the young pretender in England. Many things can be told of our simple Germans and Quakers and fiery Scotch-Irish Presbyterians that would lead you to a better understanding, but I must go on and tell about David. This is the time that we find the handles of his plow and the fences marked with soapstone where he had paused at the end of a wavering furrow to rest his horse and work out some problem that had begun to trouble him far across the field. In after years his younger brother Benjamin was prone to tell of this figuring with pride in a budding genius, though his previous telling may have been taken as evidence of times of idleness, for it was said David rested old Dobbin overlong at the end of the furrow.

Coming home from the old papermill our hero made a waterwheel and then a clock, a wooden one with three wheels, but not content with this he soon made others, using brass for the works. In this he was encouraged by articles in Poor Richard's Almanac upon the regu-

lation of clocks. So he and his mother finally persuaded father Mathias to buy sufficient tools and materials to set him up in a shop by the side of a road.

His every clock was different and better than the last, for he studied and improved his mind. Some days when he had finished a task and needed a new one he would walk the twelve miles to the school of Patrick Menan at Marble Hall, where every student was in a class by himself, more especially David. Men in America had learned to walk from the Indians. David was only five years old when the Indians first felt themselves cheated by the Walking Purchase, and he had early walked to Shipback and Salford, where Christopher Dock, the first American writer on school management, taught on alternate days. A man could and often did outwalk a horse in those early trackless days. And walking is good for thinking.

In 1751, when David was nineteen, Thomas Barton, a graduate of Dublin University, came to teach school at Norriton and opened up a new world of learning. They started a lending library so as to pass on the good things to others, and the next year Barton became a tutor in the academy, which soon became the College of Philadelphia, to which had come the able, energetic and discerning Rev. William Smith. In 1753 Barton married, at Old Swedes, David's favorite older sister, Esther. About a year after this Barton sailed for Europe to obtain orders as a rector of the church of England and returning brought many scientific books to add to what David was obtaining from the college and the library of James Logan. So filled were David's days and nights in attempting to keep up with this torrent of learning that he had a breakdown, and sensibly stopped all work and took the baths at Sulphur, now Chester Springs, and later those near his brother-in-law's farm at one of his charges in what was then York County. Recovering from this illness he was ever afterwards plagued, as he described to his nephew, William Barton, "with a constant heat in the pit of the stomach; affecting a space not exceeding the size of half a guinea attended at times with much pain," and which disturbed him greatly in the position of writing.

In 1756 he made an eight-day clock for Thomas Barton, which had on the upper dial plate "Tempus Fuget" and beneath "Mind your business." This clock was lost in New York or carried to England. In the year 1758 Barton was chaplain to one of the king's American regiments. He says that he rode out to meet Colonel Washington coming with troops from Fort Cumberland, and finding Washington on foot dismounted and walked back with him seven miles. He tells afterwards of the perils with the Indians and of his preaching for Washington on Nehemiah 4:14. It was through Barton that Rittenhouse became acquainted with Washington, for whom he made a surveyor's compass, and much later spectacles and a reading-glass. In 1763 Rittenhouse and Provost William Smith were making surveys to connect Lake Erie by water with the Delaware, before any canal was built in England, and thus prevent the loss of the lucrative Western trade to New York and Baltimore. Ever since the first granting of Penn's charter there had been a dispute between Penn and Baltimore. Cresap said that "Philadelphia was the damndest, prettiest city in Maryland," and Penn's claim would have taken in even the present Baltimore City and given him a port on Chesapeake Bay, probably Oxford, Robert Morris' old home. The charter granted land to Penn from the beginning of the fortieth to the beginning of the forty-third parallel of latitude. When all the previous charters had been granted, a degree of latitude was thought to be only sixty English miles. J. Picard

of France announced in 1671 that the length of a degree of latitude was nearly seventy common miles. There is a question as to whether Newton knew accurately the size of the earth or whether he was held up that twenty years because he did not know how a sphere attracts an outside particle, as Adams and Glaisher claim. The preponderance of opinion apparently favors the old explanation, as voiced by Noyes in his "Watchers of the Sky":

. . . Newton withheld his hope
Until that day when light was brought from France,
. . . To the throng,
Those few corrected ciphers, his results,
Were less than nothing; yet they changed the world.
For Newton seized them and, with trembling hands,
Began to work his problem out anew.
Then, then, as on the page those figures turned
To hieroglyphs of heaven, and he beheld
The moving moon, with awful cadences
Falling into the path of his law ordained,
Even to the foot and second, his hand shook
And dropped the pencil. "Work it out for me,"
He cried to those around him; for the weight
Of that celestial music overwhelmed him;

You will also see what a trouble and mess this made out of the old grants to have a degree nearly ten miles longer than it previously had been. The claims of Maryland were thought to have been settled by the Chancery Court decree issued in the year of Rittenhouse's birth, but the dispute still hung on and in 1763–64 Rittenhouse was employed by the Penns, through the Reverend Richard Peters, then their secretary, to make intricate calculations and to fix certain points of the twelve-mile circle about New Castle, for which he says he was handsomely paid. We know that in 1767 Mason and Dixon, after a short stay at the Plumstead house, No. 30 South St., designated as the most southerly point of Philadelphia, loaded their instruments in a wagon and went directly to what is now called Harlan's Corner, near the Chester County Poor Farm and spent the winter there, and that there remains in the shifting sands of a field above the house the so-called Star Gazer's Stone. Immediately south of the house was their observatory, from which they measured a south line crossing the Brandywine three times in the first mile. They continued this and on a part of it measured out a degree of latitude. This line is over four miles east of the eastern boundary of Maryland. They probably didn't want to make any of their preliminary calculations on Lord Baltimore's territory. Finally, they measured fifteen miles south from the then position of the stone which was in the latitude of the most southerly part of Philadelphia. From this point they proceeded to locate the northeastern corner of Maryland and to lay out Mason and Dixon's line. The method was to start off from each station on the arc of a great circle, just as steamers do to-day, then at intervals they checked back south on the meridian to the latitude of their starting point. In this manner they continued until stopped by Indians.

Pennsylvania had been settled first by the English, who carried on the peaceful tradition of the Swedes and Dutch. Next came a great shock-absorber belt of Germans and on the outposts the Scotch-Irish, who without let or hindrance felt that no Christian should be without land while the savages had so much. In 1763 both Barton and Rittenhouse were much incensed at the so-called Paxton riots. Some friendly Indians who had sought the protection of the government were interned in the barracks and prison at Lancaster. They were set upon by the Paxton boys and all killed; the last one, a little boy who had been clinging to the rafters of an outhouse, was dragged down by an old greybeard and held by one hand while

his brains were blown out by the rifle held in the other. Immediately the old preacher dropped on his knees in the blood of the boy and praised God for the deliverance. Excited by their success, the Paxton boys marched on Philadelphia to destroy the Indians there, but were delayed in Germantown and persuaded to return. On the other hand, the Reverend John Ewing, first provost of the University of the State of Pennsylvania, gives us a much lighter story of the Paxtons and blames the Indians, much as did Jonathan Edwards in New England. In 1765 Samuel Purviance wrote Colonel James Burd "to let it be spread abroad through the country, that your party intend to come well armed to the election—and that you will thrash the Sheriff, every inspector, Quaker and Menonist to jelly," but all was in vain as yet.

In February, 1766, at Norriton, the Reverend Thomas Barton united David Rittenhouse and Eleanor Coulston, the daughter of a neighboring farmer, in marriage, he having assumed the family estate by taking upon himself certain obligations generally belonging to the younger son. Here on the 23rd of January, 1767, was born his oldest daughter, Elizabeth, named after his mother, and later, 1788, the wife of Jonathan Dickinson Sergent, and on December 1, 1768, a second daughter Esther, named after his favorite sister, and in 1789 the wife of Dr. Nicholas B. Waters. On November 17, 1767, the College of Philadelphia had bestowed upon him the degree of Master of Arts, "being well assured of the extraordinary progress you have made by a felicity of natural genius in mechanics, mathematics, astronomy, and other liberal arts and sciences, all of which you have adorned by a singular modesty and irreproachable morals." This same year he commenced the observatory at Norriton, made a mettaline thermometer and investigated the compressibility of water.

The year 1769 was an extremely busy one. Not only did he settle the boundary between New York and New Jersey, but he was busy making all the instruments for observing at Norriton the transit of Venus, which occurred on June 3rd of that year. The legislature had appropriated one hundred pounds, and the newly organized American Philosophical Society had appointed a committee which was to meet at State House Yard, Norriton and Cape Henlopen. The public contributions and the public money were principally at the disposal of the State House committee, where a small wooden platform was erected for the observations of the subcommittee headed by Dr. John Ewing. This observatory was the stand from which was first read the Declaration of Independence.

It was owing to the patience, skill, labor and public interest of Rittenhouse that the Norriton observatory became the chief part of the enterprise. Here Dr. Smith used a reflecting telescope sent by the Penns through Dr. Rush and later to be the property of the college. There was also an astronomical quadrant of 2½ foot radius made by Sisson. This instrument was similar to the smaller one made by Rittenhouse and afterwards used by Andrew Ellicott, surveyor general of the United States, now preserved in the Smithsonian Institution. Rittenhouse used this quadrant for obtaining the latitude of the observatory at Norriton and it was returned to New Jersey, where we trust it has been preserved. Rittenhouse also made an equal altitude instrument, a transit telescope and of course a most excellent clock. All these are now the property of the American Philosophical Society and the University of Pennsylvania. The calculations from the Nor-

riton and Greenwich observations, as given in the Appendix of the Astronomical Section of the First Volume of the transactions of the American Philosophical Society, gave the sun's horizontal parallax as 8.805″. You may read both the American and European correspondence in this same volume.

The transits 1739 and 1761 had been unlucky. Reverend Horrox, who calculated the one of 1639 the first observed, had to attend service while it was in progress. The British everywhere met clouds or were prevented by the French. Mason and Dixon were chased home by the French and reluctantly sailed a second time. All Maskelyn had to show for a visit to the West Indies was a seven hundred dollar liquor bill and a new method for obtaining longitude. The Leipzig observer who had gone far enough north to prevent the sun setting in the midst of things was accused of falsifying his records, but many years afterwards the eminent American astronomer, Simon Newcomb, proved that the accuser was both color blind and mistaken. One Frenchman, Le Gentil, prevented by the English from landing, stayed eight years longer in the East Indies till 1769 and found it cloudy and so came home, for he wouldn't have a chance again until December, 1874. Rittenhouse also observed the transit of Mercury, November 9, 1769.

At this same time Rittenhouse was working on his orrery, a name gotten from the fact that the Earl of Orrery unwittingly patronized a planetarium whose plan was stolen by one Rowley from its inventor, George Graham. The King of England paid Rowley a thousand guineas, though the instrument only contained the sun, earth and moon. The financing of the Rittenhouse machine is the first instance of a research fund in America. Barton wrote to Rittenhouse:

> I would have you pursue your Orrery in your own way without any regard to an ignorant or prevailing taste, all you have to study is truth and to display the glorious system of Copernicus in a proper manner and to make your machine as much an original as possible. I beg you will not limit yourself in the price. P.S. I beg leave to recommend Huyguns, Cotes, Horshams, and Powers philosophy to you. I wish you would purchase Bion's description of Philosophical and Mathematical instruments.

Dr. Witherspoon, president of Nassau Hall, now Princeton, rode out to Norriton and paid Rittenhouse three hundred pounds for his orrery, to be finished later. It was a source of great pride and of many appropriations to the college until it was lost some time after its return from the Chicago World's Fair of 1893. The second orrery, finished nearly as soon as the first because of the need of importing brass from England, cost the University of Pennsylvania nothing. Rittenhouse received forty-two pounds and ten shillings after a great deal of labor by him, and Smith, Parnell Gibbs and John Folwell were paid sixty-five pounds for making its magnificent case. The always generous legislature of that day awarded David Rittenhouse three hundred pounds as an appreciation of his genius. The "Vision of Columbus" alludes to it as follows:

> See the sage Rittenhouse, with ardent eye,
> Lift the long tube and pierce the starry sky;
> Clear in his view the circling systems roll,
> And broader splendours gild the central pole.
> He marks what laws th' eccentric wand'rers bind,
> Copies Creation in his forming mind,
> And bids, beneath his hand, in semblance rise,
> With mimic orbs, the labours of the skies.
> There wond'ring crowds with raptur'd eye behold
> The spangled Heav'ns their mystic maze unfold,
> While each glad sage his splendid Hall shall grace,
> With all the spheres that cleave th' ethereal space.

Rittenhouse came to Philadelphia expecting to be appointed to a position in

the Land Office at two hundred pounds a year, but owing to a sudden adjournment of the legislature this did not happen. Very soon after arriving in the city his young wife died, and the visit of a comet was only a momentary comfort, even though he caught Winthrop of Boston in an error.

Early in 1771 he was elected one of the secretaries of the American Philosophical Society, and in the latter part of the year, at the instigation of Richard Peters, he was elected to take charge of the orrery and to give occasional lectures at the college. He also took the position of caring for the State House clock. The years 1771 and 1772 find him of a mind to go to England and exhibit his orrery. His state of mind is such that his little niece, Hetty Barton, whose commonplace book is preserved at the university, accuses him of being in love and we find him marrying Hannah Jacobs on the very last day of 1772. In 1773 he was appointed a commissioner to make the Schuylkill navigable, and in 1774 to settle the boundary between New York and Pennsylvania. He and Captain Holland, of the British Army, established the northeast corner of Pennsylvania, but because of the intense cold did no more until 1787. In May, 1775, the American Philosophical Society petitioned the legislature to establish a Colonial observatory and appoint Rittenhouse the director, because he could not only direct the observations but he could make all the instruments, but Lexington and Concord had been fought. Nobody has ever satisfactorily explained the coming of the revolution. John Adams said that the crisis had occurred ten years before. Somehow, before England or America realized it, the revolution was on. Charles Thomson felt that had the Whigs in the legislature been let alone they would have united the whole Province, rich and poor, for the old families highly valued their long-held seats in the legislature. So Franklin and Rittenhouse, being the only men known throughout the state, were brought into the conflict to give it the authority of their partisanship. Franklin and Rittenhouse were appointed on the committee of safety, of which Franklin was chairman and Rittenhouse the engineer. Rittenhouse was on the Council of Safety, of which he was vice-president, and the Board of War of the Supreme Executive Council. He was one of twenty-four men having the power of life and death. We find him making a survey of the River Delaware and the surrounding country for fortifications and laying out the forts which resisting, after Washington's defeat at the battle of Brandywine, would have made the British position untenable had the decision of Germantown been in favor of the Americans. Finally, they were destroyed after great loss. He made and rifled cannon. Joseph Galloway said before the English Parliament that the American artillery depot was at Norriton in 1776. Also we find him designing with his friend, Owen Biddle, iron clock weights to exchange for lead ones. Charles Wilson Peale and he almost put their eyes out experimenting with telescopic sights on rifles. They might have been much more hurt if Peale's cartridge box had not fallen open and lost him his ammunition on the way to the proving grounds.

Rittenhouse was elected to Franklin's seat in the legislature and afterwards to the Constitutional Convention, where after a few days' preliminary skirmishing he was made chairman of the committee of the whole, so that he or Franklin then presided at every session. Cannon, Rittenhouse and Jacobs, his brother-in-law, were appointed to write the preamble and oath. The committee was loaded against Cannon and from the

Roberts collection at Haverford College there is very great evidence that he was more of a talker than a writer or doer, even though he is known as the author of the letters of Cassandra. Franklin and Rittenhouse and Vanhorn were on the committee to recast the wording. Much has been said for and against this constitution. When examined closely it is a Unicameral constitution along the lines of the British instrument and does not have the conservative checks and balances of the constitution of 1789 which was made to conform to the similar one of the constitution of the United States. Some of the different features were a prohibition against continuous office-holding, which must have been objectionable to McLean, whose double office-holding in two states so excited an old German that he would not vote for a bill establishing a life insurance company, saying "if we do this old McLean will get insured and he'll never die and he'll hold office forever." Also there was a board of censors elected every seven years to criticize the constitution, its manner of administration and to advise changes in method and to make amendments. There was early opposition, but it was smothered. Soon after this Rittenhouse was elected state treasurer and the constitution allowed him to accept no other office.

I will not speak of the terrible winter of Valley Forge, when Provost Smith lived near Valley Forge on the Island of Barbadoes, opposite what is now Norristown and which was later proposed as the site for the university. When Mrs. Rittenhouse and her daughters dwelt at Norriton, David stayed with William Henry at Lancaster and even General Mifflin joined the "Conway Cabal" till Cadwallader closed Conway's lying mouth with a bullet. As soon as the British left Philadelphia Rittenhouse drove from Lancaster to Philadelphia with his instruments and a load of household goods and within a week was engaged with Smith and Biddle in making the first really scientific observations in America of an eclipse of the sun. These observations are preserved in the handwriting of Provost Smith.

Thomas Jefferson wrote to him July 19, 1778, "I sincerely congratulate you on the recovery of Philadelphia," inquired after the orrery and Rittenhouse's papers, and then went on to say, "though I have been aware of the authority our cause would acquire with the world from its being known that yourself and Dr. Franklin were zealous friends to it and am myself duly impressed with the sense of the arduousness of government and the obligations those are under who are able to conduct it; yet I am also satisfied there is an order of geniuses above that obligation and therefor exempted from it. Nobody can conceive that nature ever intended to throw away a Newton upon the occupations of a crown. . . . I doubt not there are in your country many persons equal to the task of conducting government: but you should consider that the world has but one Rittenhouse, and that it never had one before. The amazing mechanical representation of the solar system which you conceived and executed has never been surpassed by any but the work of which it is a copy."

Parson Odell wrote in 1779 in the *Royal Gazette:*

There dwelt in Norriton's sequestered bowers,
A mortal blessed with mathematic powers,—
To whom was David Rittenhouse unknown?
Fair Science saw and marked him for her own.
His eye creation to its bounds would trace,
His mind the regions of unbounded space.
While thus he soared above the starry spheres,
The word of Congress sounded in his ears;
He listened to the voice with strange delight
And swift descended from his dazzling height.

Soon after this in 1779 the legislature, in spite of a clause written by Dr. Smith

and put in by Franklin to prevent this very thing, dispossessed the college and erected the university of the State of Pennsylvania to carry out its projects and use its resources and those of sequestered estates. Smith went to Chestertown, Maryland, and established Washington College. Rittenhouse was appointed, because of his political position, trustee of the new university, but was in 1779 elected professor of astronomy and later in 1780 vice-president and could no longer be trustee. At the time that Smith temporarily gave up the fight in '82, Rittenhouse resigned his professorship and was immediately elected trustee and soon thereafter, through the enterprise of Francis Hopkinson, the orrery seal was adopted as a compliment to the great scientist. Finally, in 1789, after nearly thirteen years of service, Rittenhouse resigned as state treasurer, having been defeated at the polls as a candidate with Franklin for the old constitution. He had had some respite from the fatigues of this office in finishing the southern boundary of Pennsylvania and the western boundary to the Ohio and later the eastern part of the northern boundary, which he ran through a dense wilderness, by getting the latitude of points on a random line with zenith sectors of his own making and correcting back on the meridian. Rittenhouse and Ewing also ran the boundary between New York and Massachusetts at the request of Congress. During these journeys, in spite of the fatigue and great exposure, he was in much better health and was joyous and popular with his associates. The visits of great men in that day as in this excited the emulation of those less scholarly. On June 1, 1785, on Mason and Dixon's line while awaiting the arrival of Rittenhouse, Andrew Ellicott tells of the talents of Major Brownfield, who rode up to the meeting place of the commissioners and shouted "Hoollo, the host, the host, take my laborious dumb animal and put him in a separate department by himself, and give him proper nutrils such as a dumb animal may consist on and I will abscond for it in the morning." Ellicott often speaks of the wide vista they can see, reaching back ten, fifteen and from a high elevation even forty miles, the hundred-feet-wide clearing looking like a thread in the distance. He describes their way of living, saying they "arise in the morning about six or seven, they observed the sun's altitude between seven and ten, dined between twelve and one, after which we always drink our two bottles before leaving the table, then observe the sun's corresponding altitude, at six we have a large bowl of wine syllabubb. This rule we never break—we have each of us a cow. We drink our tea about seven and sometimes observe the heaven's the greatest part of the night." In December, 1785, he paid a long visit to Rittenhouse and they went together to talk with Benjamin Franklin. Again in the next April he arrived in Philadelphia on the 19th, visited with the New York Commissioners on the 20th, 21st and 22nd and is delighted with Miss Hetty Rittenhouse's vocal music. On the 23rd of April, still being at the Rittenhouse's he enters the following in his diary:

> April 23rd—Not only being Sunday but likewise the birthday of my friend Mr. Rittenhouse—he was born April 23rd, 1732, and one of those instances where strength of genius independent of a liberal education or even the common advantages has raised himself a monument of fame more durable than all the glittering pomp attendant on wealth and power—without tutors and almost without the aid of books he mastered the most critical and sublime parts of science and is now justly esteemed the first astronomer in this new world and perhaps inferior to none in the old—his life is as remarkable as his genius with a modest diffidence ever attending merit added to his most prudential conduct has secured his fame without creating one enemy or exciting envy.

Spent great part of this day at William Barton, Esquire. He is a most judicious gentleman and valuable citizen—and was presented by himself with some of his political writing.

He was a fellow of the American Society of Arts and Letters, 1782; a member of the Virginia Society of Arts and Sciences, 1785; a foreign member of the Royal Society of London, in 1795. In 1790 he succeeded Franklin as president of the American Philosophical Society. Three times he received the honorary degree of master of arts; from the University of Pennsylvania 1767, William and Mary 1784, Princeton 1782, and doctor of laws from Princeton 1789. He was connected with the College and University of Philadelphia, the University of the State of Pennsylvania, and the University of Pennsylvania from 1771 to 1796, until 1779 as lecturer and in charge of the philosophical apparatus, for a brief period trustee and then until 1782 professor of astronomy and vice provost of the university, and trustee thereafter. It was Rittenhouse, unless Fantana preceded him, who first used spider threads for cross-hairs in his telescope, besides inventing the collimating telescope in 1785. It is interesting to note that though engaged in arduous public work he published on the average one paper every year from 1780 to 1796, many highly original and over a wide field—on optics, Fraunhofer gratings[1]; optical illusions, modern psychology; magnetism, Ewing's principle; electricity, fourteen experiments with Kinnersley; logarithms, model and expert computation. One was read on March 3, 1780. The instrument maker, Short of London, found, when using his Cassegrain telescope alongside a reflector, that the mountains of the moon became valleys and *vice versa* and he discarded the instrument. Rittenhouse looked through a telescope at a brick pavement in his fireplace. The bricks looked sunken and the joints raised. At first he thought it was a necessary complement to the inverting of the image, but being a scientist he had to be certain, so he took out the lenses to find the same illusion. He shut off all but one window with no effect. Then he used a mirror in the fireplace, upon which alone a ray of sunlight fell. This caused things to look natural and he repeatedly alternated this effect. Then he put his finger on the bricks and the trouble at the same time, and his mind, realizing his own flesh and blood, corrected the illusion and after a few trials was fooled no more. What a lesson in morals. We need something to hold on to and after we have held on several times we can go alone.

On February 6, 1781, he struck a soft ramrod several times on one end while it was held parallel to a needle of a surveyor's compass. He reversed it and similarly demagnetized it. Then he noticed that placing the rod perpendicular to the needle gave no such effect. This is a modern notion called Ewing's principle. The great philosopher adds, "from this does it not seem very probable that during the concussion of the stroke and whilst the magnetic particles of the rod were more disengaged from the surrounding mass the active power above mentioned seized them and arranged them properly, when being confined, the rod afterwards remained magnetized. All this is nevertheless little more than conjecture until confirmed by further experiment."

He invented a wooden hygrometer in 1782, concerning which Robert Adrain, professor of mathematics at Rutgers, Columbia and Pennsylvania, wrote a generation later.

All this time he was in the clock making business, as witness this advertise-

[1] See T. D. Cope, *Journal* of the Franklin Institute.

ment, Philadelphia, May 20, 1786, in *Dunlap's Advertiser:*

Wanted—an ingenious lad not exceeding fourteen years of age of a reputable family as an apprentice to learn the art and mistery of making clocks and surveying instruments. Any lad inclined to go an apprentice to the above trade, the terms on which he will be taken may be made known on inquiring of Mr. David Rittenhouse in Philadelphia or at the Subscriber's in Worcester Township, Montgomery County.

BENJAMIN RITTENHOUSE

The first translation of any German play into English was Minna Von Barnhelm in England in 1786. Rittenhouse translated within a year a play of Lessing's which had an English setting. It was called "Miss Sarah Sampson, or The Unhappy Heiress." Rittenhouse's translation is called "Lucy Sampson," with the same sub-title. He also translated the "Idylls" of Gessner from the French. The *American Magazine* published his drawing of the Ohio Phyle Falls. Besides this, he was greatly interested in any fiction that he could get his hands on, feeling that it was very stimulating to his imagination. It would make a very interesting bookshelf, had we placed there his favorite fiction and on another shelf, of probably equal size, his philosophical and mathematical reading list.

On the stormy night of Franklin's death in 1790 Provost Smith wrote impromptu:

Cease, cease, ye clouds, your elemental strife!
Why rage ye thus, as if to threaten life?
Seek, seek no more to shake our souls with dread!
What busy mortal told you Franklin's dead?
What though he yields at Jove's imperious nod?
With Rittenhouse he left his magic rod!

President Washington appointed David Rittenhouse the first director of the United States Mint on April 14, 1792, and he remained in charge of the mint until June, 1795, when declining health compelled him to resign. Mr. Barber, late engraver of the mint, executed a bronze model of Dr. Rittenhouse. Possibly excepting Duvivier's head of Washington after Houdon, it can not be surpassed in the cabinet. "The engraver had a very fine subject and treated it in the highest style of art." The United States Mint was authorized by an Act of Congress, April 2, 1792, just twelve days before Rittenhouse's appointment. Soon afterwards, a lot of ground was purchased on Seventh Street, near Arch, and appropriations were made for erecting the necessary buildings. In an old account book, we find an entry on the thirty-first of July, 1792, of the sale of some old materials of the still house which had stood on that lot, for seven shillings and sixpence. This sum of money "Mr. Rittenhouse directed should be laid out for punch in laying the foundation stone," which cornerstone was laid by David Rittenhouse as the director of the mint on that same day. Coinage commenced the following October. This was of silver half-dismes, of which Washington makes mention in his address to Congress, November 6, 1792, as follows: "There has been a small beginning in the coinage of half-dismes; the want of small coins in circulation calling the first attention to them."

In the years 1792 and 1796 Rittenhouse and Jefferson worked out a definite scheme for making a standard foot, a definite part of the length of a pendulum, ticking seconds in the latitude of Philadelphia. A system of weights and measures on the decimal scale was admirably devised, preserving most adequately the common measures known and used by all. This measure was finally passed after a most interesting debate in May, 1796, but the Senate had

adjourned without concurring, so we still have ninety-six kinds of bushels in the United States.

In the latter part of June, 1796, Rittenhouse during several very hot days gave personal attention to the drawings from the wheel in the canal lottery. His meteorological diary shows his hand growing weaker, until on the 26th of June the entries cease. On June 27, 1796, Moreau de Saint Mery, who had been king of Paris for a day, had been refused a ticket to the Assembly ball because he kept a bookstore in Philadelphia and who was afterwards a provincial governor under Napoleon, writes: "Yesterday I attended the funeral rites here of the celebrated Dr. Rittenhouse, American astronomer whose loss his country most justly mourns. He was buried in the floor of the Observatory which he had had constructed in his own Garden. What a philosophic union, perishable ashes with an edifice consecrated to the observation of the most sublime marvels of nature! What a rapprochement between the genius of man and his nothingness!"

Finally, on July 4th, 1796, another hand again writes the entries in the diary that was David Rittenhouse's, and the record goes on seemingly as before.

THE DEVELOPMENT OF SOCIOLOGY

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I. The Movement for Social Betterment and the Origins of Sociology

While the problems with which sociology concerns itself have been discussed by philosophers since the days of Oriental antiquity, sociology first definitely appeared, properly christened as a specific department of social science, about the middle of the nineteenth century. A large number of factors contributed to its origins, among them the growing interest in man and society and an increasing knowledge of the nature of man and his physical environment. Probably the most important influence creating sociology was, however, that general groping for social betterment which was produced by the misery that came in the wake of the industrial revolution and the factory system.

In the writings of certain early sociologists, this impulse to social betterment emerged in concrete utopian plans for a more happy and perfect system of social and industrial relations. With certain other writers, like Saint-Simon and Auguste Comte, it made its influence felt by suggesting that sociology should be a science of social progress. Such writers opposed sociology, thus conceived, to the well-meant but often naïve contemporary programs for social improvement.

On the other hand, such sociologists as Herbert Spencer, Ludwig Gumplowicz and William Graham Sumner were chiefly interested in developing the science of sociology to furnish irrefutable proof of man's inability to improve his social surroundings through any conscious effort at an artificial redirection of the trend of social evolution. It is apparent, therefore, that with both the enemies and friends of social reform it was this urge to social reconstruction which gave rise to the science of sociology.

II. The First Period of Sociology: Analogy, Definition, First Principles and Systematization

The first half century or more of sociology was given over chiefly to the effort to bring about a transition from social philosophy to social science. During most of this period writers approached the subject of social origins and social processes primarily from the standpoint of dogmatic *a priori* assumptions, sweeping generalizations and heroic efforts at systematization and at a synthesis of sociological information.

The first generation of sociologists after Auguste Comte were influenced chiefly by the effect of Darwinism upon social science. One school devoted itself mainly to an elaboration of the analogy between the individual organism and human society. These writers endeavored to show that human society exhibited in its organization systems of organs possessed by the individual biological organism. While often grotesque in matters of detail, this body of doctrine was of significance for social science in the way of emphasizing the necessity of a proper coordination and harmony between the various constituent groups of human society.

The other group of early biological sociologists devoted their attention primarily to illustrating the alleged analogies between biological evolution and social evolution, laying stress chiefly upon the similarity between the strug-

gle for existence in biological evolution and the function of war in social evolution. This school of so-called "Social Darwinists" contended that in the same way that the struggle for existence had been the dynamic factor in the evolution of organisms, so war had been the chief constructive process in the evolution of humanity. It must be pointed out, however, that Darwin himself never sanctioned any such sociological interpretation of his evolutionary theories, and the title "Social Darwinism" was appropriated by this group without the approval of Darwin himself.

While enormously overemphasizing the importance of a single social process, this school made an important contribution by pointing out the very great services of war in bringing an end to tribal society and in creating the origins of the political or territorial states which were to give to society that order and security essential to the further progress of civilization.

A large group of writers were dissatisfied with this tendency to be absorbed either in elaborating the analogies between the organism and society or in emphasizing the social significance of human warfare. They turned to: (1) a discussion of the scope and methods of sociology and of its relationships with the natural sciences and the other social sciences; (2) definitions of its chief concepts; and (3) the clarification of its province.

The so-called methodological discussions which this trend in sociology produced gave rise to much heated altercation between the exponents of these diverse interpretations of the nature, purpose and methods of sociology. It absorbed a great deal of energy in the somewhat sterile and unproductive task of definition, classification and demarcation, but there is no doubt that the net result was a clarification of the sociological atmosphere and a more general agreement as to the subject-matter and objectives of sociology. In other words, this sort of work represented the inevitable and essential preliminary period of definition and classification which marks the early stages of all science, natural or social. Certain writers, such as Georg Simmel and Albion W. Small, devoted their lives chiefly to these problems of definition and methodology.

Paralleling these battles over definitions and methods was a comparable conflict among the sociologists as to the basic factor in the social process and the key to the development of a system of sociology. For example, Gabriel Tarde contended that the elementary social facts were to be located in the process of imitation; Emile Durkheim maintained, on the contrary, that the key to society lay in the impression of the group mind upon the individual psyche; Alexander Sutherland, Prince Kropotkin and others defended the assertion that the vital fact in the social life of man was to be found in sympathy and mutual aid; Gumplowicz and his disciples expounded the opposite thesis that it was in war and social conflict that one was to look for the core of the social process; Franklin H. Giddings asserted that in the consciousness of kind and differential reaction to stimulation one could discover the only valid basis for the construction of the principles of sociology; Gustav Ratzenhofer and Albion W. Small found in human interests the only rational clue to an understanding of social activity and organization; and Guillaume De Greef and Alfred Fouillée defended the contention that contractual relationships between individuals and societies constituted the *rationale* of society.

The debates thus generated gave rise to a large amount of acrimony and personal recrimination, but they stimulated each writer to the most effective defense of his particular thesis, with the resulting enrichment of our knowledge of the

nature and potency of all these very important social influences and processes. The discriminating sociologist of the present day takes little stock in the all-sufficiency of any one of these unilateral views of society, but they each helped to create that body of subject-matter out of which a reliable synthesis can now be constructed. The growing recognition of the inadequacy of single-track interpretations of the social process has likewise produced that salutary and desirable tolerance among sociologists which was so notably lacking a generation ago.

The fourth significant characteristic of this earlier stage of sociological science was the effort of the leading writers to achieve a comprehensive systematization of sociological theory. Auguste Comte's system was given over chiefly to a comprehensive philosophy of history and an elaborate plan for the future reorganization of society along the lines of what he believed to be scientific principles. Herbert Spencer devoted himself to an attempt to interpret the origins and organization of society in terms of his particular formulae of cosmic evolution, incidentally giving some attention to the analogy between the organism and society and demonstrating to his own satisfaction the futility of social uplift. Lester F. Ward, taking his departure from Comte, exploited the terminology of natural science, particularly that of botany, to prove the original supremacy of the female sex and to demonstrate the possibility and desirability of conscious social reform guided by an ever-improving body of sociological knowledge.

Giddings, more eclectic and less dogmatic than these earlier writers, exploited and synthesized the great majority of sociological writings prior to his time in what was the most impressive and comprehensive system of sociology formulated prior to the opening of the present century. His particularistic emphasis upon the consciousness of kind was worked in as the primary item in a broad view of the origins and processes of society. Ratzenhofer and Small constructed a system of sociology about a classification and schedule of those vital human interests which give rise alike to individual activity and the organization and struggles of human groups. Hobhouse salvaged from the wreckage of the organic analogy the basic fact of the desirability of a harmonious coordination of social groups and classes and argued for a growing control by human knowledge and the human mind over the processes of social evolution. A similar point of view was elaborated by Ludwig Stein in Germany. One of the latest efforts at a system of sociology, that by Professor Franz Oppenheimer, is constructed upon an exploitation of the history of human society and the economic elements in the conflict of social classes. The most elaborate recent system of sociology is that of Dr. Leopold von Weise. He regards sociology as a study of the social process, conceived of mainly as "inter-human" relationships and behavior.

It is now very generally conceded that most of these efforts to produce comprehensive and finished systems of sociology were premature. The knowledge upon which a fairly secure synthesis could be built was not available when most of these writers formulated their concepts. Further, it is doubtful if the energy or mentality of any individual is adequate to a thorough mastery of the vast range of facts essential to sociological synthesis. Nevertheless, these early systems of sociology were in no sense a total loss. They called attention to the general nature of sociological material and vindicated for all time the importance of the sociological type of analysis. They also provided the point of departure for subsequent discussion and criticism.

III. Contemporary Sociology and the Trend of Specialization

In the place of ambitious efforts at an all-embracing synthesis of sociology in the form of closed systems, the dominant trend in sociological science since about the opening of the twentieth century has been toward the splitting up of sociological endeavor among various groups of scientific men interested in one or another phase of the social process. Some have given their attention to a consideration of the problems of an adequate sociological methodology. Others have become interested in the relation between the physical environment and social processes. Another group has devoted itself to a consideration of the bearing of the facts of modern biology and genetics upon the origins, organization and future of human society. A large number of writers have surveyed and analyzed the wide range of psychological factors affecting the groupings and activities of men.

Another school has applied its efforts to a reconstruction of the course of cultural and social evolution. They have traced out the various stages in the development of the present-day forms of social organization and cultural expression, indicating as far as possible the various factors which have brought about the transition from the cave-dweller to the modern urban tenant, with all the social and cultural implications involved in this transformation. Then, the problems of social organization have attracted the attention of a large and active corps of workers in the sociological field. Finally, perhaps the most diverse and enthusiastic contribution to the literature of sociology is to be found on the part of those who are attempting to use the facts assembled by social science in the last century as the basis of more reliable and convincing plans for social and economic reconstruction than could be offered by the Utopian Socialists of the age of Robert Owen.

The progress of scientific method and specialization in the field of sociology can be well illustrated by the advances within each of these divers fields of approach to sociological analysis. In the first place, there has been an enormous improvement in the last twenty-five years with respect to both the exactness of method and the depth of knowledge possessed by the so-called specialists in particular fields of sociological study. In the second place, the process of specialization has been carried on so as to embody specialization within specialisms. For example, few social scientists would to-day contend that it is possible for them to master all the geographical factors affecting human society or all the biological processes which are of significance to the sociologists. It has become necessary, in other words, for the anthropogeographer or the social biologist to specialize upon a certain restricted range of problems and interests within his particular field.

In the cultivation of sociological methodology the first generation of students was absorbed chiefly with problems of definition, classification and the demarcation of the province of sociology. At the present time, this sort of work has been almost entirely abandoned, and we find those interested in methodology concerned with such problems as the application of statistical measurement to social processes, the analysis of the methods and limitations of the cultural approach to social origins and social organization and the consideration of the methodology essential for the study and comparison of the intelligence and social interests of definite human groups and cultures.

In other words, the generalized study of methodology has been supplanted by an examination of the utility and limi-

tations of particular and relatively exact methodologies. The important fact is that all of them insist upon an ever greater utilization of the exact quantitative methods of natural science and a relative abandonment of the *a priori* and deductive technique of social philosophy. There is a general agreement that sociology can become a true science of society only in the degree to which it is able to appropriate and apply those exact methods of measurement and analysis which constitute the indispensable attributes of science in general. William F. Ogburn and his sympathizers and followers have been especially earnest in emphasizing this point.

In studying the absorbing and stimulating problem of the effect of the multifarious influences of the physical or geographical environment upon man in human society we find a corresponding progress away from sweeping and dogmatic generalizations and towards concrete study of the influence of particular geographical factors upon specific groups of men dwelling in well-defined geographical regions. The older anthropogeographers, from Ritter and Peschel to Ratzel, Reclus, Kirchhoff and Semple, attempted to present a systematic and comprehensive survey of the operation of all the so-called geographical "influences" upon man and society. With the progress of knowledge in this field, it became more and more difficult, however, for a single student to master all the facts involved in the various phases of the incidence of the environment upon man. Hence, we discover a growing tendency towards the specialization of writers upon some single type of geographic factor, such as climate, topography, routes of travel, waterways and routes of water communication, meteorological factors and alteration of geographic influences by the progress of the material culture of man.

But this is not all. Following the suggestions of the great French geographer, Paul Vidal de la Blache, and his disciples in other countries, the most advanced school of anthropogeographers have even come to doubt the feasibility of a generalized study of any one of these special geographic factors or influences. They contend that anthropogeography can become truly scientific only through an exclusive concentration upon the study of the effects of specific geographic factors upon a group of men inhabiting some very definite geographic region. In other words, regional physical geography has been followed by recognition of the inevitability and necessity of regional anthropogeography.

Further, the modern scientific anthropogeographer no longer proceeds from the naïve assumption of geographical determinism, but adopts the cultural point of view of the modern critical anthropologist and cultural historian. He recognizes that human culture is the dynamic element in society and civilization, and simply endeavors to discover the particular ways in which culture is conditioned by the geographical factors operating upon the inhabitants of the particular region studied. When one compares such a summary of the contemporary point of view as Lucien Febvre's "Geographical Introduction to History" with one of the best syntheses of the older generalizing anthropogeography, such as Miss Semple's English adaptation of Ratzel, he realizes the extent of the progress made in this field in the last generation with respect to both the degree of specialization and the precision of methodology.

The same advances toward detailed specialization and greater exactness of scientific method is to be observed among the biological sociologists. We have already pointed out that the first generation of biological sociologists concerned themselves primarily with an elaboration of such hypothetical analogies as the theory of the social organism

and the doctrine of Social Darwinism. There was little effort to study in a scientific fashion well-founded biological processes and to discover through detailed observation their bearing upon the problems of human society. Such interests and activities as characterized biological sociologists thirty years ago have now become thorough anachronisms in the field.

In the first place, we have the demographers, represented by such men as Willcox, Thompson and Kuczynski, who are interested in gathering and classifying the facts descriptive of the social population, thus collecting the raw material for theoretical students of the problem. Along with these we have the students of the theory of population. They take their cue from Malthus and are known in general as Neo-Malthusians, primarily because of their reliance upon birth control, which Malthus had refused to sanction. These writers, well represented by Professor East, author of "Mankind at the Crossroads," are concerned with the quantitative aspect of population, namely, (1) the relation between the increase of population and the means of subsistence, and (2) the bearing of this situation upon the prosperity and progress of human society. They are, in general, sympathetic with the birth control movement as led by Mrs. Sanger and others, holding that the chief avenue to social well-being is to be found mainly through some practicable method of maintaining the population at the level which will insure a relatively high standard of living, assuming the existence of an adequate technology and an efficient economic system. Certain members of this school have endeavored to formulate laws of population, qualifying or supplementing the original generalizations of Malthus.

Another important group of writers concentrate their attention upon the qualitative aspects of the population problem. They are concerned with the biological evolution of man, the question as to whether civilization has had a disastrous effect upon the biological quality of the human race, and the whole issue of eugenics, involving the problem of the possibility of the artificial improvement of the physical quality of the human stock. Writers like Otto Ammon, Karl Pearson, Edwin Grant Conklin and Samuel J. Holmes represent discriminating scientific exponents of this point of view, which has been set forth in a more popular and exuberant fashion in the writings of Mr. A. E. Wiggam.

Finally, there should be noted the physical anthropologists and the scientific students of race and racial characteristics. Such scientific men devote themselves to the ascertainment of the physical criteria of race and to the accumulation of exact facts with respect to the physical traits of the major races of mankind. In carrying their researches beyond physical investigations to an analysis of the mental traits of the various races, they link hands with the differential psychologists. The work of the physical anthropologists, admirably represented by men like Arthur Keith, Rudolph Martin and Aleš Hrdlička, together with that of the differential psychologists and the cultural historians, offers the best possible antidote to the vagaries of Madison Grant and his disciples who have been busy in recent years disseminating the Nordic rehabilitation of the old Aryan myth.

These various groups of scientific students of the biological foundations of society are at last making available the relevant facts and processes of biology, so that they may be appropriated in an intelligent fashion by the alert legislator and discriminating social worker. Only superstition and bigotry prevent us today from undertaking a speedy adoption

and application of their more significant and demonstrably valid recommendations.

Psychological sociology likewise had its origins in the last quarter of the nineteenth century with writers who dealt in broad and sweeping dogmatisms concerning such complex and general psychological factors as custom, imitation, fashion, impression, emulation, sympathy, etc. At this time there was little or no reliable technical psychology to be learned, and these writers possessed but a slight familiarity with even such psychology as existed. While some progress took place in the interval between 1890 and 1910, as exemplified by the sociological interests of psychologists like Baldwin or the better mastery of psychological principles by a sociologist like Cooley, it may safely be said that the first treatise on psychological sociology which demonstrated the author's comprehensive familiarity with the facts of reliable psychology was C. A. Ellwood's "Sociology in its Psychological Aspects," published in 1912. W. I. Thomas's mastery of social psychology had been demonstrated mainly by a number of erudite articles and monographs.

Yet this ambitious attempt at synthesis to be found in Professor Ellwood's useful book did not set the pattern for the development of psychological sociology in the next decade. Rather, we find an altogether commendable tendency toward further specialization and a more thorough cultivation of technical psychology. The popularity of the instinct hypothesis, launched by the appearance of Professor McDougall's book in 1908, has provoked a vast amount of controversy and has resulted in a general clarification of this problem, the best synthesis now existing in the field being Professor Bernard's monograph on "Instinct." The behavioristic impulse, emanating from Watson and Max Myer, has been exploited for social psychology by Allport, Burnham and a number of others who are interested in the important social applications of the theory of the conditioned-reflex.

The social significance and applications of Freudianism have been examined and exploited in a discriminating fashion by Martin, Groves, Ogburn, Holt and Thomas. An extremely promising effort has been made to work out the all-important synthesis of behaviorism and Freudianism by Allport, Martin, Hamilton, Young and others, a development which has been hampered by the vigorous rhetorical, but somewhat illusory, opposition of Watson to Freudianism. The psychology of the crowd is now beginning to be studied in a scientific fashion by Martin and others. The significance of habit-forming complexes for psychological sociology has been indicated in detail by Ellwood, Dewey and Gault. Wundt, Hall, Lévy-Bruhl, Paul Radin, Goldenweiser, James Harvey Robinson and others have devoted themselves to a study of the psychological history of the race, clarifying the similarities and contrasts between the thinking of primitive and modern man.

The provision of scientific and practicable methods of mental testing by Binet, Simon, Goddard, Yerkes, Terman, Otis and others has made possible the development of differential psychology, a technique of the greatest significance for the further analysis of the problems of eugenics, mental hygiene, criminology, immigration and democracy. Finally, the necessity of abandoning a theory of psychological determinism and adapting the psychological theories of society to the notion of cultural conditioning has been recognized by nearly every group now interested in psychological sociology. The most ardent exponents of this point of view have been the critical anthropologists of the Boas school, and Graham Wallas, F. C. Bart-

lett, W. I. Thomas, C. A. Ellwood, W. F. Ogburn and F. Znaniecki.

The net result of these labors has been to put at our disposal a vast body of relevant psychological information of the greatest practical significance for human betterment and a more adequate and penetrating conception of social processes. Nothing could more effectively illustrate the progress in psychological sociology in the last generation than a comparison of such books as Gustave Le Bon's "The Crowd," or Gabriel Tarde's "Laws of Imitation," with Allport's or Young's "Social Psychology."

In the study of the history of human society there has been notable progress away from the *a priori* philosophy of history characteristic of the early stages of historical sociology. Building upon the firm foundation of the laws of cultural development established by the critical anthropologists and upon the vast array of facts concerning social and cultural evolution gathered by the conventional historians, the students of social and cultural history have been able to work out a most impressive survey of the history of human culture from the Old Stone Age to the Hoover prosperity. There has been an escape both from the inaccuracies of the old philosophy of history and from the irrelevancies of the episodical and anecdotal historians of the conventional academic school of history-writing. In this field, as in others, specialization has been necessary, as no single student of social evolution could personally master the technical equipment or the body of facts involved in a survey of the totality of human cultural development.

The study of the facts and problems of social organization has attracted a varied group of authorities. The forms of social organization have been discussed in great theoretical detail by Georg Simmel. Simmel's conclusions have been made intelligible, as well as accessible, to English readers by his disciple, Dr. N. J. Spykman. The biological basis of social organization has been analyzed by writers such as Gini, Pearson, Carr-Saunders, Ammon, West, Holmes, Kelsey and Hankins. Tarde, Durkheim, Wallas, Cooley, Ross, Ellwood, Bernard, Bogardus, Young, Williams and others have devoted their attention to the psychological factors involved in the organization of society. The economic aspects of the question have been investigated by Loria, Sombart, Weber, Schmoller, Webb, Hobson, Hammond and Cole, by Veblen and the institutional economists, and by Professors Seba Eldridge, Charles Austin Beard and others interested in the economic basis of politics. The political foundations of social organization have received especial attention from Gustav Ratzenhofer, Robert Michels, Graham Wallas, Harold Laski, Albion W. Small, A. F. Bentley and F. H. Giddings.

The most significant fact about all these modes of approach as specialized forms of analysis of social organization is that the old obsession with definition and classification has been superseded by a concern with the vital and dynamic processes involved in the origins of social groups and their mutual conflicts and adjustments. Much of the credit for this wholesome change is due to Ratzenhofer and Small.

The reaction of these various phases of progress in scientific sociology upon social work and social reform has forwarded the ultimate realization of the ambitions of the founders of sociology to create a scientific guide for the betterment of mankind. On the whole, social work has abandoned the ideal of amelioration and has adopted the slogan of prevention, the key to which is to be derived from a mastery of the scientific facts of sociology.

Sociology, properly understood, does not discourage "uplift." Indeed, it

would seem that the chief vindication of sociology is its real potential service to the cause of increasing the happiness and prosperity of human society. What sociology does insist is that uplift shall cease to be governed by theological and sentimental motives and shall found its objectives and methods upon the indisputable facts wrought out by sociology in the last quarter of a century.

The extensive advances in the subject-matter of sociology, as well as the increasing tendency towards specialization, which have been all too briefly summarized in the preceding paragraphs, make it obvious that the future of sociology must decisively be a co-operative matter. Any synthesis of the field by a single individual is doomed to result in either grotesque inaccuracies or in the superficialities compatible only with a brief text-book survey of the field.

IV. The Influence of Sociology upon the Special Social Sciences

We should at least make passing mention of the influence of sociology upon the other social sciences. Its effect upon the study of history has been chiefly to emphasize the fact that man does not function as an individual but as a member of a group; to aid the progressive historian in his analysis of the various forms of institutional life in which man participates; and to emphasize the conception of civilization as a genetic and dynamic process. Sociology has been particularly useful in promoting a broad and synthetic view of the processes of historical causation.

Sociology has been able to offer a number of helpful suggestions to open-minded economists, for example: emphasis upon the group basis of custom and fashion which determine to so large a degree the nature of economic demand; an indication of the interrelation of the economic with the other factors in the social process; and a clarification of the nature of the social institutions which condition the operation of the economic factors in society.

On no other special social science has the influence of sociology been more significant than with regard to political science. Sociology has furnished indispensable information as to the nature and foundations of political control and has cleared up many obscure problems related to the origins of the state. It has also given a real *rationale* to politics by indicating the social process which goes on within the state and by making it clear that the real function of the state is to act as an umpire of this social process. The influence of sociology upon jurisprudence is comparable to that upon the science of government. Sociology has emphasized the social origins and function of law; has indicated the fundamental social basis of all valid legal principles and has emphasized the function of progressive jurisprudence in the way of social engineering and the guidance of social change.

The sociological influence upon ethics has been revolutionary in theory, however little it may have affected conduct in practice. It has made clear the group basis of all ethical guides and criteria, however dogmatic a social group may be with respect to the allegation of the divinely revealed nature of its ethical concepts and practices. Sociology has also emphasized the necessity of adopting a secular basis for the judgment of commendable conduct. It insists that the object of ethics should be to produce an ever greater number of happy and efficient human beings here upon the earth, and not to save a vast throng of souls eagerly quitting their earthly misery.

The relationships between sociology and esthetics have not been adequately cultivated thus far, but the group foun-

dation of esthetic judgments is readily apparent, and enough has already been done to indicate the real importance of art as a form of social expression and a mode of social control. With the gradual secularization of human interests we may predict that esthetics will ultimately come to occupy the position held by theology in the interest and affections of the early sociologists.

The most important general effect which sociology has had upon all the special social sciences is to emphasize continually the unity of the social process and to promote a synthetic point of view on the part of all types of social scientists. This guards against the narrowness and superficiality which invariably accompany a partial view of the processes and institutions of society.

V. Obstacles to the Development of Sociology

In spite of the remarkable strides which sociology has made in volume of subject-matter and increasing exactness of its methods, it has made relatively slow progress in achieving academic recognition, in receiving adequate consideration from legislators and public officials, and in securing the good-will and confidence of the general reading public.

There are a number of causes of this situation. The first might be called the "euphonistic" obstacle, namely, the confusion of sociology with socialism because of the similarity in the pronunciation of the two words. This may seem preposterous, but the writer believes it to have been more important than any other influence in prejudicing the average timid and conservative citizen against sociology. Even the librarian of one of our foremost graduate schools in this country fiercely opposed sociology and sociological books for a generation because of his firm belief that a socialist and a sociologist were one and the same person in each and every case.

In the second place, we must consider the opposition of pure and pious folk, who look upon sociology as a subject which undermines morality and leads to atheism. When properly taught, sociology must of necessity provide the foundation for any valid body of morality or any social religion. It is true, however, that sociology analyzes with frankness and candor the anachronisms in the present moral code and Fundamentalist religion. Hence the alarm with which half-educated people view the teachings of sociologists.

At the same time, these "vile" sociologists, as they appear to the late Mr. Bryan and not a few college professors, are viewed with a mixture of amusement and pity by those in real touch with life and its problems. There is no doubt that three fourths of our American academic sociologists would read such an innocuous if illuminating book as Miss Kirchwey's "Our Changing Morality" or Professor Joad's "Thrasymachus" with unmitigated horror and disgust. Over half of them would gladly lock arms with the late Wayne Wheeler and John S. Sumner. Likewise, most of them are thoroughly "sold" to the capitalistic system and the "theories of the leisure class," a fact which removes them from active contact with the campaign for social and economic reconstruction.

Hence, those on the "firing line" of cultural, social, economic and ethical advance will have nothing to do with the majority of the sociologists. What appears to the pious and respectable as unmistakable proof of depravity and revolutionary radicalism on the part of sociologists seems to the realists and reformers to be nothing less than pedantry, ignorance, prudery, hypocrisy or infantile timidity.

Another recent form of opposition to sociology arises from progressives who fear the alleged pernicious influence of

foundations and endowments. Much current sociological research is subsidized by the great foundations which have been endowed by very wealthy men interested in preserving the existing social, economic and political order. Naturally, most subsidized research must carefully avoid projects likely to result in unsettling discoveries, or, if such results do emerge, they must be obscured. Such considerations, as Benjamin Stolberg has amply indicated, hamstring both scientific candor and the practical value of sociological research.

Again, we must list among the powerful sources of opposition to the progress of sociology the jealousy of the other social sciences. History, economics and political science were established as academic subjects from a half century to a century earlier than sociology. This has given them a stronger hold upon the faculties and administrative boards of the colleges and universities. The opposition of these older vested interests to sociology has been intensified by the fact that the vivid human appeal of sociology has attracted to sociology courses large numbers of students who would otherwise have been swelling the class registers and enhancing the local prestige of solemn and respectable teachers of history, political science or economics. Therefore, in certain institutions, such as Princeton, Harvard, California, Cornell and Johns Hopkins, together with most of the aristocratic New England colleges, sociology has been excluded altogether or has been offered in an inadequate and misleading fashion by professors of economics. In many institutions, such as Wisconsin, while courses in sociology are tolerated, the instructors in sociology have been kept under the general control of the department of economics or government.

To the opposition of the vested interests of the older social sciences must also be added the even more vigorous antipathy of the departments of mathematics, science, literature and other even older and more respectable departments and vested curricular interests.

The future of sociology is a matter for prophecy and not for history, and we are only concerned in this article with history. The place that sociology will occupy in the future of human thought and action will depend upon a multitude of factors, some connected with sociology itself and others with general trends in the public mind.

Before sociology can command the unqualified respect and support of intelligent and thoughtful persons it must divest itself of a sentimental adherence to indiscriminate efforts at uplift; it must reject whole-heartedly the impurity-complex which it has inherited from its Puritan and ministerial ancestry; and it must reduce the paralyzing influence of discipleship and dogmatism to which all the social sciences are in differing degrees susceptible. The degree to which it will influence social thought and action will also depend upon how far society surrenders its contemporary submission to rhetoric, convention, tradition and propaganda, and demands competent technical and scientific guidance.

If it be objected by many that sociology has not yet secured a sufficiently high level of agreement among its various schools, and that it has not yet perfected its methodology with adequate scientific precision, it may safely be answered that it will probably remedy these defects long before society will be willing to accept its constructive assistance.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

STEEL WITHOUT RUST

By Dr. JOHN JOHNSTON

DIRECTOR OF RESEARCH, UNITED STATES STEEL CORPORATION

THE fact that iron and steel rust under many of the usual conditions of service is only too well known to all of us; it is less widely known that the loss due to rusting each year is, as estimated by competent authorities, to be reckoned in terms of millions of tons of metal and in hundreds of millions of dollars. The properties of steel are so valuable, indeed so unique, that the world wishes to use it for all sorts of purposes, and so tries to offset its tendency to rust by applying to the steel surface some sort of protective coating. Familiar examples are: by electroplating the steel with copper, nickel, chromium or other metal; by coating it with another metal, with tin, as in the familiar tin can, or with zinc to make the so-called galvanized iron, or with lead; or with a glass or vitreous enamel, as in the familiar enamel-ware; or by covering the surface with paint or tar or other similar materials. But none of these coatings designed to protect the steel from the ravages of the rusting agents—principally oxygen and water acting together—is entirely satisfactory, and a very great deal of effort has been expended in endeavoring to secure improved protective coatings on steel at a reasonable cost.

A great deal of effort has also been put forth in experimental work aiming to lessen the rate of rusting of iron by addition of alloying elements, with little success except in two instances, both discovered some 20 years ago. First, the presence of about ¼ per cent. copper in steel slows down markedly its rate of rusting and destruction in the atmosphere, and has proved to be especially advantageous in steels exposed to industrial atmospheres, as in and near cities; this type of steel, which is sold as copper-steel and also under various trade-names, costs little more than ordinary steel, slows down the rate of rusting in the atmosphere, but is not rustless. Second, the discovery was made that addition of chromium to the extent of 12 per cent. or more renders the iron substantially rustless under many conditions of use. This was a rather surprising discovery, for chromium is not inherently a noble metal in the sense that gold and platinum is: indeed, it is really less noble than iron, but has the power of covering itself, rapidly and automatically, with an invisible, very thin, oxide film which, when formed, protects the metal underneath from further attack. It retains this power of forming a protective, impervious, oxide film even when alloyed with iron, provided that the alloy comprises more than about 12 per cent. chromium; and this is the basis for all the recent rapid development of the so-called stainless steels, their stainlessness being in all cases due to the chromium which they contain.

It is of interest to note that the element chromium had been known for more than a century before it was really put to work, as a metal, for the world. This delay in making use of chromium is due in part to the comparative diffi-

culty of extracting it from its ores, but mainly to the presumption that it would exhibit no outstandingly valuable properties. Moreover, it was thought of as rare, but its ores prove now to be at least as abundant in the earth's crust as are ores of copper, and to be much more plentiful than ores of lead or of tin, all of which are not usually thought of as rare metals. It is true that chromium still is—and is likely to continue to be—rather expensive as compared to the wonderfully cheap metal iron, and therefore that steels containing enough chromium to render them stainless must inevitably cost considerably more than ordinary steels. But stainless steels, which now cost no more than ordinary steels cost a century ago, render special service, which for many purposes justifies their extra cost.

This group of steels is substantially rustless under nearly all ordinary conditions of use; to be precise, these steels are rustless under oxidizing conditions, as in the atmosphere, provided that the final heat treatment of the alloy was carried out in the appropriate manner. They are, however, not entirely resistant under some conditions of service; but no metal can be expected to withstand corrosion completely under all conditions of environment—even the noble metal gold or platinum is not entirely resistant in all places where we might wish to use it.

The rustless or stainless steels and irons may, for convenience in this brief discussion, be divided into three fairly distinct groups.

The first group, and the earliest in point of time, comprises the stainless steels which are properly called steels because they are hardenable upon appropriate tempering. They contain 12 to 14 per cent. of chromium with relatively high carbon, and are used mainly for cutlery.

The second group comprises the stainless, low-carbon steels, or, more properly, irons, because these alloys are not hardenable by heat-treatment; they usually contain about 17 per cent. or more of chromium and relatively low carbon. They are rustless under many circumstances but not entirely satisfactory under the severest conditions of exposure; their use is therefore limited largely to special industrial applications.

The third group, which is the group arousing the greatest interest at the present time, comprises the alloys containing nickel as well as chromium and iron. The most commonly used contains about 18 per cent. chromium and about 8 per cent. nickel, with relatively little carbon; it is often called simply 18–8, but bears a great variety of tradenames. It is one of the group of so-called austenitic stainless steels, the term austenitic referring to the fact that in this group the iron is caused, through the influence of the alloying elements, to be present at ordinary temperatures in the austenitic, or gamma, non-magnetic crystal form.

In this connection it may be noted that the uniqueness of steel as a useful metal, the fact that it can be tempered and so readily made hard or soft, ductile or brittle, depends primarily on the circumstance that iron is the only common metal which readily assumes either one or other of two different crystal forms. These two forms differ markedly in specific volume, the change of volume being obvious when one transforms into the other; in heat-content, so that there is an evolution of heat—the so-called recalescence—when the gamma form passes over into the alpha form; and in their capacity for holding in solution carbon and other alloying elements; indeed, they behave almost as two different metals, though composed of the same iron atoms in different arrangement. The properties of the finished steel article are controlled by controlling the occurrence of this transformation. This

heat-treatment of steel is, of course, a very ancient art, long kept secret by those who practiced it; its basis has been understood only in very modern times and the art has become a science open to any one.

To return now to the austenitic type of stainless iron alloy, the principal alloy of this group, namely, that containing 8 per cent. nickel as well as 18 per cent. chromium, is perhaps the most important of all the stainless types at the present time, because of its much wider applicability. It has of late been used rather widely for decorative purposes on the outside of buildings as well as on the inside for doors, for panels and trim of various kinds, and on automobiles, partially replacing chromium plating; also for restaurant equipment, kitchen utensils, hospital ware and for many other similar familiar purposes. It is being used on a considerable scale in the chemical industries, including the refining and cracking of petroleum; and with some slight modifications of composition and treatment, which now are known to obviate troubles occasionally encountered by some of those who have used it for such purposes, its use in the modern chemical industry is likely greatly to expand. It takes on a high polish, which it retains indefinitely in the ordinary atmosphere; it is ductile, yet exceedingly strong, considerably stronger than ordinary steel and particularly so at temperatures approaching red heat. Moreover, it is quite resistant to attack by oxygen at high temperatures, and so it can be used in places, such as furnaces, where parts made of ordinary steel would have only a short useful life.

The remarkable strength of this austenitic type of alloy, both at ordinary temperatures and at high temperatures, indicates that it will have an extensive field of application apart altogether from the more or less decorative uses, now familiar to us, which depend mainly upon its essential rustlessness. Its use offers possibilities of structures which for a given strength are lighter, consistent with complete safety, than if made of any other metal or alloy now used.

The development of this very useful type of alloy—a development which has resulted, directly or indirectly, from the labors of many men, in various countries—is another example of the advantage which accrues to the world from the systematic careful investigation of the potentialities of materials derivable from the raw materials available to us. Primitive man used as materials only those found naturally; for untold centuries man had to be content with a very small added number obtained by simple means from his raw materials; and it is only with the development of the science of chemistry—which began as a science about 150 years ago—that he has become possessed of a large number of new materials which have enabled him sometimes to do new things, sometimes to do old things in a better way. Yet the research worker does not, strictly speaking, create anything except values; what he does is, by painstaking exploration, using as a guide and interpreter the previous accumulation of experience known as science, to discover just what properties are inherent in substances of one kind or another, and how to combine them to get a useful result. This becomes a new technical advance if, after suitable development—which is usually expensive both in time and in money—it can be realized at a price the world is willing to pay for it. In the case of the stainless and rustless steels and irons, all of which contain at least 12 per cent and usually 18 per cent. or more of the element chromium, this development has now proceeded to a point at which the world is increasingly ready to pay for them, by reason of the remarkable properties possessed by these alloys.

WHAT DO YOU WEIGH TO-DAY?

By RALPH W. SMITH

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"What do you weigh to-day?" That arresting question, boldly lettered on a person-weighing scale, flings its challenge to a dieting world from hotel lobby, drug store, railroad station and street corner. And when it reaches you do you accept the challenge and promptly climb aboard the person weigher to resolve the doubt? You probably do, for an opportunity to weigh one's self is a lure which it seems few can resist.

The importance of these scales has recently become so great that their proper regulation was one of the subjects discussed at a recent national conference of weights and measures officials—those officers whose duty it is to supervise commercial scales and weights and weighing and measuring in general. A code of specifications and tolerances was proposed which would require scales intended solely for the weighing of persons to be as accurate as scales of similar general characteristics used for the buying and selling of merchandise. Person weighers would also be required to have what is known as a "free zero"; that is, the construction would be such that a clear and definite indication of the zero balance condition would be given at all times, so that the prospective customer may assure himself before he invests his penny that the scale is properly balanced and ready to start right from scratch.

Perhaps people will not avail themselves of this opportunity to avoid scales which are out-of-balance at zero. Too many folks seem to believe that anything which looks like a scale will give correct weighing results. I once saw a woman step blithely onto a scale, deposit her penny, read the indicated weight, and go her way entirely satisfied, when all the time there was staring her in the face a "condemned" label, four or five inches in diameter, placed squarely in the center of the scale dial by the weights and measures official to show that the scale had been found inaccurate upon test. An indicator which does not exactly coincide with the zero graduation would probably mean little or nothing to such a person. But it is a theory of weights and measures supervision to provide the customer with reasonable means to protect his interests; if the public do not avail themselves of the means for self-protection which are provided, they must suffer the consequences in inaccurate weight results.

Then there is another class of requirements in this code intended to protect the customer in spite of himself. For example, some person-weighing scales may have an ungraduated interval between zero and some fixed point, throughout which interval the scale is not designed to give weighing results. It is provided that on such a scale, if a fond mother tries to weigh her child whose weight falls within the no-weight zone, her penny must automatically be returned to her. On a scale which issues tickets showing the weights of persons weighed, it is demanded that when the scale becomes inoperable by reason of the exhaustion of the supply of tickets, any pennies inserted in the slot during the continuance of this condition shall automatically be returned, or the insertion of a coin in the coin slot shall automatically be prevented.

Numerous types of person-weighing scales are in use, but not all of these will be covered by the code of the National

Conference on Weights and Measures. For it is only when a fee is charged for the weighing service that the scale becomes "commercial" in the weights and measures sense and subject to official supervision and test. All that large aggregation of free weighers, bath-room scales, and other types on which the insertion of a coin is not a prerequisite to a weight indication, will continue to be unregulated, for it is only when the weighing assumes a commercial aspect that the state or city, in the exercise of what the lawyers term the "general police power," can step in and enforce regulatory measures.

And even the penny scale can live an untrammelled life in some communities—at least until the laws are amended. For once upon a time a clever defense lawyer, whose client was in trouble with the local department of weights and measures on a matter involving charges for laundry work at so much per pound, delved into the statutes and discovered to his satisfaction that the law specifically mentioned "commodities and things" but was quite silent about "services." He represented to the court that his client was selling neither commodities nor things but only a laundering "service," in view of which he contended that the weights and measures law did not apply to his client and his scales.

In its wisdom, the court found the argument valid and the defendant was discharged, thus excluding from the jurisdiction of that department matters having to do exclusively with service, as distinguished from commodity. The person weigher and its operation fall in this class; the scale is not intended to determine amounts of commodity bought or sold but merely performs a weighing service for the information and satisfaction of the weigher. However, when the scale charges for this service it is selling the service, and the transaction becomes commercial and subject to the supervision of weights and measures authorities wherever their authority embraces services as well as things.

Since the time of the court decision mentioned, some states have amended their weights and measures laws to include within their purview sales of service as well as sales of merchandise; fortunately, also, the weights and measures laws of all states, as originally worded, were not as restrictive as the statute mentioned. So it is to be anticipated that the ubiquitous person weigher will be regulated and supervised and tested in many states, and that the good effects of this supervision will be felt, insofar as new scales are concerned, even in those states where the present laws will not permit testing, because the manufacturers may be expected to discard from their lines models which do not conform to the requirements of the code of the national conference.

However, a public, eager to be weighed, will still have many styles to choose from, even if considerable elimination takes place. One may patronize a tall scale with a slender pillar and a large circular dial, or, if graceful curves are not appealing, one may choose a scale modeled on severe, straight lines; plate glass mirrors are available on some scales to cater to the eternal feminine and the semi-occasional male; if one prefers an atmosphere of surgical cleanliness, there is the scale finished in white porcelain and tile. Short-pillared scales, on which one looks down rather than ahead or up to read the weight indication, and which may be constructed to conceal the weight indication from all except the person being weighed, are a recent development, and in these, modernistic ideas of exterior design and unconventional color schemes will be found. Ticket machines, which for your penny tell not only your weight but also your fortune and perhaps even include a photograph of a distinguished aviator or a popular actress, may be patronized.

And now comes a foreign manufacturer with the announcement that he has developed an "all talking" scale which will announce the weight of a person, presumably in well-modulated tones. Whether or not some other manufacturer will go so far in developing the phonograph idea as to produce a scale in which the good or bad news, as the case may be, will be accompanied with appropriate advice on how to keep on getting thinner or how to build up an emaciated physique, remains to be seen. It is not clear how such a machine might be made to discriminate and select the proper advice for each of its clients, but whatever method might be used, the advice would probably be as appropriate as the "fortunes" which ticket scales now hand out regardless of sex, age or present condition of servitude.

Anyway, it has been proven that people like to "get weighed," and are willing to pay for the opportunity; and enterprising individuals are making it just as pleasant and easy and convenient as possible for people to gratify this desire. It is said that the nation has become "weight conscious." To what extent this consciousness may be charged to the designers of frocks, the manufacturers of breakfast foods, the vendors of reducing recipes and remedies and the advice of life-extension institutes can not be said.

Perhaps no small part of the tremendous volume of public person weighing is done with the laudable desire of keeping a check on one's health and general physical condition. But more fundamental than this is the unexplained but very real and deep-seated urge to get weighed, which seems to be the common heritage of most of us.

Now if you see on a person weigher a paper sticker or a metal disc or a lead plug which indicates that the scale has been "sealed" by the department of weights and measures, this means that the scale in question has been tested with test weights and found correct. But keep a weather eye open for a tag indicating that the inspector has "condemned" or "rejected" the scale upon which you contemplate weighing yourself; in such a case save your penny for some other scale, for the ominous tag means that something is wrong and that you will not get a correct weight on that scale until repairs have been made.

A penny is not much, but even so there are those who simply must weigh themselves, but who so hate to part with the customary copper that they resort to the use of slugs. Numerous coin-operated vending machines have been developed in which the mechanism ingeniously and automatically applies a series of tests to determine the genuineness of the coins inserted. Some of these machines are said to apply as many as nine or ten separate coin tests—for over and under diameter, over and under thickness, over and under weight, milled edge, rim, center hole and magnetic properties. If there is any room left inside the housing of such a machine, there would be a wonderful opportunity for using a phonograph attachment. How pleasing it would be to the customer who has made tender of legal coin for the machine to thank him graciously for his patronage; and how appropriate that a raucous reproof be administered to one who tries to beat the machine with a lead slug or a brass or iron disc.

The importance of a coin-testing mechanism is, of course, much greater in the case of a vending machine where the value of the required coin or coins is relatively large, than it is in the case of the penny scale; moreover, if the scale receives a slug this merely means a loss of profit for the operator, whereas the operator whose vending machine accepts a slug loses not only his profit but also what he has invested in the article dispensed. Yet if the loss of revenue resulting from the use of slugs becomes

sufficiently serious, it is probable that the manufacturers of coin-operated scales will follow the lead of the vending device manufacturers so as to protect the interests of the purchasers or lessees of their scales.

Finally, if you are one of those with a weight complex, and if your weight appears to vary considerably from day to day, don't be too quick to blame the scales. In the first place, errorless scales are just as rare as perfection in any other line. A scale is considered to be "correct" when its error does not exceed the allowable tolerance in either direction; it is plain that two scales might be "correct" and that yet one scale might have a minus error and the other a plus error, which would result in some difference in the weight indications on the two scales for exactly the same load. In the second place, remember that the human body is far from being constant in weight and may vary several pounds throughout a single day, depending upon the time of day, the temperature, the amount of food and drink taken into the system and similar factors. If you want a real check on whether or not you are losing or gaining weight, weigh regularly on the same good scale and do your weighing at approximately the same time and under the same bodily conditions every day. If you do this, you will know at all times just how you stand with your old friend avoirdupois.

MAKING BACTERIA INVISIBLE AND ITS SIGNIFICANCE

By Dr. J. P. SIMONDS

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FIFTY years ago on the 24th of last March, Dr. Robert Koch read a paper before the Berlin Physiological Society, in which he proved that the tubercle bacillus is the cause of tuberculosis. This was an epoch-making discovery. A year before, at a meeting of an International Scientific Society in London, he had described a method by which bacteria could be grown on solid mediums in pure culture. As soon as Dr. Koch had finished reading his paper, the great Pasteur, who was in the audience, rushed forward as fast as his partially paralyzed leg could carry him, enthusiastically shouting, "C'est un grand progrès." (This is a great advance.) Using Koch's method and applying his principles, scientific men discovered the bacterial agents which cause many of the well-known infectious diseases—diphtheria, typhoid fever, cholera and many others.

These newly discovered bacteria seemed always to form on artificial culture mediums the same type of colonies, *i.e.*, aggregations of microbes in sufficient numbers to form a visible mass, and to have the same shape and staining qualities, no matter from what source they had been isolated. Hence the doctrine of fixity of bacterial species, that is, that a species of bacterium always showed the same cultural and structural characteristics under like conditions, came to be an accepted tenet of the science of bacteriology.

This doctrine of fixity of bacterial species held undisputed sway for more than thirty years. But ten or fifteen years ago some bacteriologists began to be skeptical about the truth of this doctrine. Skepticism is a useful habit of mind in a scientific man. They observed the phenomenon of pleomorphism, that is, bacteria known to be growing in pure

culture assumed atypical and even bizarre shapes. Somewhat later it was found that bacteria descended from a single isolated parent microbe would produce on artificial culture mediums colonies that were not characteristic of the species. Some of these colonies were smooth and glistening and had regular borders; others had rough surfaces and irregularly wavy edges.

The still more startling discovery by Drs. Twort and d'Herelle of the bacteriophage was popularized by Sinclair Lewis in his novel "Arrowsmith." Bacteria that were growing vigorously would suddenly disappear in spots, giving the originally uniform, growing mass a moth-eaten or Swiss-cheese appearance. Microscopic examination of these spots or holes revealed that the bacteria had completely disappeared, or at least had become quite invisible. It was at first believed that the bacteriophage was a sort of fatal infectious disease of the bacteria themselves and caused their complete destruction.

For many years it has been known that the germs of certain infectious diseases are so minute that they can pass through a compact stone filter and are too small to be seen with the most powerful microscope. This group of germs is known as filter-passing or ultramicroscopic viruses. They cause a great number of diseases, such as the mosaic disease of plants; certain tumors and diseases of the blood of chickens; distemper of dogs; pleuro-pneumonia and foot and mouth disease of cattle; and smallpox, vaccinia, measles, rabies, influenza, common colds, infantile paralysis, and several other diseases in man.

This is the background of the very important and possibly epoch-making recent work of Dr. Arthur I. Kendall, professor of research bacteriology, in Northwestern University Medical School. The following description of this work is largely a condensed report of the lecture in which Dr. Kendall announced his new method and the result of its use.

There is a heterogenous group of formidable diseases, many of which occur as rapidly spreading epidemics, such as influenza and infantile paralysis, whose inciting agents have thus far eluded cultivation upon artificial mediums. One reason for the uniform failure to induce growth of those "viruses" outside the human body is the fact that the artificial mediums at present available for their cultivation are radically different from the tissues and fluids of the body in which they grow and induce disease. The ordinary artificial mediums contain protein degradation products, known as peptone and meat extractives, and little or no unaltered protein. The tissues of the body, on the contrary, contain unaltered protein and little or no peptone.

"A theoretical method of approach to the problem of cultivation of these refractory 'viruses,' therefore, would appear to be the preparation of a sterilizable medium containing unaltered, or nearly unaltered, protein without peptone." Dr. Kendall has prepared such a medium from the intestine of swine by extracting the fat and other substances, leaving a dried residue, composed chiefly of protein that has suffered little change. A suspension of this dried powder in Tyrode's solution, a dilute solution of several salts, and sterilized in an autoclave, constitutes the new K medium.

Dr. Kendall first inoculated several lots of this K medium with blood from cases diagnosed as mild influenza by different physicians in two hospitals. "Three of these cultures, after being incubated for several days, showed increasing cloudiness, indicating growth of micro-organisms." The filter-passing organisms isolated from the blood taken from two of the patients with symptoms of influenza induced fever and paroxysms of violent sneezing or coughing

in rabbits. From the blood of these rabbits, taken on the second day of infection, a filter-passing "virus" was again cultivated in the K medium. From these filterable cultures growing in K medium, a coccus (round, microscopically visible and non-filter-passing microorganisms) was later isolated. This coccus, in its unfilterable state, could readily be retransformed to the filterable state in K medium, refiltered and recovered again in non-filter-passing form. This microbe, therefore, can exist in two forms—a filterable state, in which condition it grows in the K medium, but does not appear to grow visibly in peptone mediums; and a non-filterable state, in which growth upon ordinary peptone-containing mediums is readily obtained. The rabbit infections were induced, while the coccus was apparently in the filterable state. Attempts to induce similar infection with the non-filterable form were unsuccessful.

While the available evidence is suggestive that this coccus, recovered from cultures in K medium of blood from patients suffering from clinical influenza, is the cause of the disease, the most significant result brought to light in this investigation is the obvious existence of the microbe isolated from these three cases in two states, a filterable and a non-filterable. It is a sort of bacteriological Ariel, which, like the Shakespearean sprite, changes its form at the order of its master.

Having shown that this coccus exists in two forms, it was suspected that other bacteria might exhibit this same dual existence, if subjected to the same cultural conditions. Such has proved to be the case. The first microorganism examined for this purpose was a culture of typhoid bacillus which had been in stock on artificial culture mediums in the laboratory for several years. It was found that this bacillus, a rod-shaped organism, can also be rendered filterable. The transformed filterable organisms fail to grow in ordinary artificial mediums, in which they grew luxuriantly before their transformation. From the growth in K medium eventually typical typhoid bacilli may be recovered.

To date, seven different species of bacteria have been transformed from non-filter-passing to filterable and back again to non-filter-passing forms. In their filterable and transition stages these bacteria appear to be more inert than in their typical forms. One or more transfers in ordinary mediums may be required to elicit the usual luxuriance of growth and capacity for chemical activity.

Dr. Kendall has observed the changes which appear to lead to the filterable state actually occurring in the typhoid bacillus in K mediums. After 15 to 18 hours' incubation in this medium, many of the typhoid bacilli lose their normal uniform structure and appear first as faintly discernible shadows, having the bacillary or rod-shaped outline. They actively swim about in the medium at this time. From two to four or more brilliantly luminous, but very tiny granules appear within the shadowy outlined organisms. Finally, the bacillary part of the organism disappears, and there remain merely the minute granules, appearing in a dark field illuminator as intensely bright, yellow oval bodies. These granular vestiges of the typhoid bacillus pass through a stone filter readily. It may be recovered in the bacillary state by appropriate recultivation.

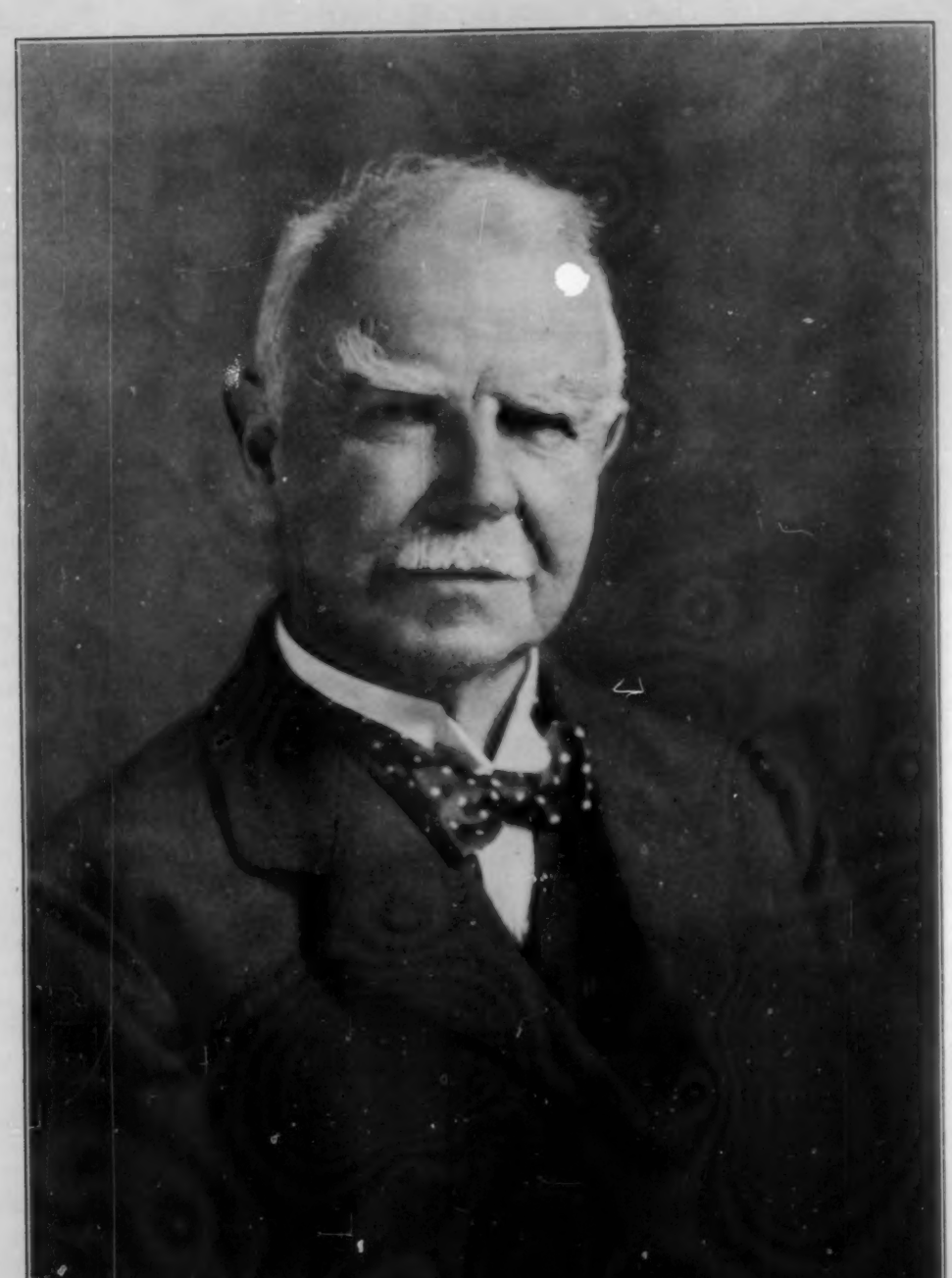
Next, it appeared that the much discussed, and not well understood, bacteriophage which passes readily through stone filters might conceivably have a similar explanation. Filtrates of staphylococcus "phage" have yielded perfectly typical cultures of staphylococcus upon cultivation in the proper manner. This observation will necessitate a reconsider-

ation and possibly a revision of our conception of the nature of the bacteriophage.

The successful use of K medium requires a considerable amount of skill and practice in bacteriologic technique. If properly employed, it will yield positive results in a high percentage of cultures from the blood of patients suffering from a variety of diseases which have hitherto yielded uniformly negative results with other methods.

What is the practical importance of this new culture medium and of the discovery of the dual existence, the "double life," of bacteria? Its full significance is not yet apparent. To learn that ordinary bacteria may change their form as readily and almost as rapidly as old Proteus in Homer's Odyssey will be most disconcerting to bacteriologists, accustomed for a generation to consider species of bacteria at least as stable and as difficultly alterable as species of cats and dogs. Almost as disturbing is the evidence that possibly the mysterious bacteriophage is merely a condition in which bacteria have, so to speak, dived below the surface of visibility, and have suffered a reduction in size as striking as that which befell Alice when she ate the magic cake in Wonderland. Like Alice they can, by proper treatment, be restored from the filterable or "phage" state to their normal size.

Dr. Kendall has supplied an explanation for the hitherto discouragingly uniform failure to isolate the causative microbe of many known infectious diseases and has furnished a workable method of overcoming this difficulty. The use of his new K medium promises to reveal much of academic and practical significance in the private life of bacteria, as well as to furnish a means of discovering the causes of many diseases. When the cause of a disease has been found, medical science has made a long step forward in its control and prevention.



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SIR ALFRED EWING

PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE BRITISH ASSOCIATION AT YORK

For its annual meeting in 1932, following the celebration of its centenary in London in 1931, the British Association returned to York, its birthplace. In a district of such varied interests, from the tranquil antiquity of the city within the walls, to the great centers of industry on the one hand, the classic fields for geology, botany and archeology on the other, which lie within a radius of a few miles, the British Association is really in its element. Whether its officers, academically robed, were accompanying the corporation in state to the Minster on Sunday morning, or whether its engineers (let us say), in far different costume, were descending a coalmine, or whatever other activities between these extremes its members might undertake, there was the justifiable sense that the association was carrying out that function for which its founders at York in 1831 designed it, "to obtain more general attention for the objects of science."

Appropriately, the president, Sir Alfred Ewing, through his inaugural address, did most to focus that attention. He directed it, under the title of "An Engineer's Outlook," toward recent advances in physics as well as in engineering; he recalled some of those which had been made through the medium of the association itself; and at the close of his address he invited consideration of what is, and what should be, the ethical connotation of some of these achievements. "What is" and "What should be" are, alas, far from synonymous. "The cornucopia of the engineer has been shaken over all the earth, scattering everywhere an endowment of previously unpossessed and unimagined capacities and powers. Beyond question many of these gifts are benefits to man, making life fuller, wider, healthier, richer in comforts and interests and in such happiness as material things can promote. But we are acutely aware that the engineer's gifts have been and may be grievously abused. Man was ethically unprepared for so great a bounty. In the slow evolution of morals he is still unfit for the tremendous responsibility it entails. The command of nature has been put into his hands before he knows how to command himself." Here was a text upon which, in the press, many persons wrote many foolish things, and a few wise ones. They do harm who preached upon this text without attempting to assimilate the lucid address which led up to it, but they do good who follow Sir Alfred Ewing in urging men toward a redress of the balance.

Those who jibe at science for becoming suddenly afraid of its own results might well (if they had the intelligence) have acquainted themselves with the intensely practical applications which were laid before many audiences at this meeting in York. Applied geophysics, stereochemistry, British overseas markets, constructive theories in psychology and sheep farming are a selection of subjects from the addresses of sectional presidents. Discussions on water pollution, railway traction by steam, oil and electric power, the control of humidity in industrial processes, the use of statistics for the business executive and the film in education are examples drawn from various sectional programs, almost at hazard. The two customary "evening discourses" were on plant products of the Empire in relation to human needs,

by Sir Arthur Hill, director of Kew Gardens; and on uses of the photoelectric cell, by Mr. C. C. Paterson, who with the aid of elaborate apparatus and skilled assistants gave the beau ideal of the demonstration-lecture.

It is not, however, to be supposed that pure science has come to take a subordinate position in the programs of the association. There are those who fear such an outcome. To one, however, who, while pretty intimately concerned with these programs, is merely an onlooker at their actual compilation by the sectional committees and the council of the association, it seems that the balance is held with much skill. The men and women of science lay before the public each year certain general topics of wide interest. They also use the occasion of the association's meeting to meet one another and discuss other subjects into which few if any laymen can follow them. It is the function of the association—implicit in that statement of objects which was laid down for it at York in 1831, and remains unaltered in its statutes—to offer occasion for both these forms of activity. So far as concerns its mandate "to promote the intercourse of those who cultivate Science," as the founders phrased it a century ago, the association performs perhaps its very best work when it provides, as no other institution can, a common meeting-ground for those whose scientific activities follow usually divergent directions; as when, at the York meeting, physicists and psychologists met together to discuss the quantitative relation of physical stimuli and sensory events.

The British Association is in the fortunate position that its meetings traditionally receive a very wide press. The presidential address and other salient features of the program obtain almost world-wide publicity by this means. It is true that journalists and scientific men may not always agree as to what constitutes a salient feature; but the association's meetings do introduce a temporary flavor of science into ephemeral literature. But this practice does not in itself provide a sufficiently strong link between science and the public understanding. It is true, again, that many of the papers read at an association meeting are published in specialist journals, and the association makes an attempt to record such publication in its annual report. In that volume the presidential addresses are printed in full, and they are also issued annually under the title of "The Advancement of Science," at the price of three shillings and sixpence. But the association suffers in common with many other scientific societies from an inability, through lack of means and of contact with the ordinary channels of distribution, to report and record at all fully the volume of the spoken words at any given meeting. That volume runs into millions. Moreover, neither the association nor any other body, even if they had the means, would benefit by attempting to make a "corner" in scientific publication. Nevertheless, more effective and wider means of publication of scientific material, adapted to the common understanding, would seem to be one of the practical steps forward from the position which General Smuts, from the chair of the centenary meeting in 1931, outlined in a sequence of ideas not dissimilar from those of Sir Alfred Ewing quoted above. "A serious lag," he said, "has already developed between our rapid scientific advance and our stationary ethical development. . . . Science must itself help to close this dangerous gap."

O. J. R. HOWARTH,
Secretary

WILLIAM PATTEN

FOR THIRTY-EIGHT YEARS PROFESSOR OF ZOOLOGY AT DARTMOUTH COLLEGE, IN WHOSE DEATH AT THE AGE OF SEVENTY-ONE YEARS ZOOLOGICAL SCIENCE LOSES ONE OF ITS LEADERS. AN ARTICLE BY PROFESSOR PATTEN ON "THE FOUNDATIONS OF THE FACE" WILL BE FOUND IN THE PRESENT ISSUE OF THE SCIENTIFIC MONTHLY. IN THE ILLUSTRATION HE IS SHOWN CHISELING OUT AN OSTRACODERM WHICH HE REGARDED AS THE "CONNECTING LINK" BETWEEN THE VERTEBRATES AND CERTAIN ARACHNOID ANIMALS.

SIR CHARLES SCOTT SHERRINGTON

THE NOBEL PRIZE IN PHYSIOLOGY AND MEDICINE

SIR CHARLES SCOTT SHERRINGTON

In conferring the Nobel Prize jointly upon Sir Charles Scott Sherrington and Edgar Douglas Adrian, the Stockholm committee explained that the award was made in recognition of the epoch-making work of these two investigators in isolating and studying the activities of individual nerve cells ("neurones"). And it might have been pointed out that the quest of the single neurone by the physiologist has had many of the dramatic features associated with the quest by the physicist of the single atom: in both cases the difficulties were exceptionally great and ultimate success depended upon amplification of minute differences of electrical potential and upon the introduction of ingenious devices for automatic recording.

Sherrington's achievement in isolating the single motor neurone represents the culmination of more than forty years' work upon the nervous system, and it is significant that in his earliest investigations (1885–1906) he had sought to interpret the activity of the brain and spinal cord in terms of the anatomical units which Retzius and others were then demonstrating microscopically by the new silver impregnation methods. Although such units continued, until very recently, to elude functional isolation, they served as the basis of all Sherrington's investigations and generalizations, including the reciprocal innervation of antagonistic muscle (1893–1909), localization of function in the motor cortex (1895–1917), levels of nervous integration (1898–1906), the principle of the final common path (1904), the proprioceptive system (1906), the nature of central inhibition (1911–1925) and of postural contraction (1915–1930), and the principle of "recruitment" (1923–1925). Until 1928–1930 the motor neurone remained a convenient anatomical abstraction, defying satisfactory functional isolation. Through a series of notable improvements in the technique of mechanical and electrical recording of reflex responses which began in 1918[1] and continued with a series of collaborators,[2] the response of each successive motor nerve unit in a gradually increasing reflex response has been placed under direct observation. The rate and characteristics of the discharge of individual motor neurones during the knee-jerk, flexor reflex and crossed extensor reflexes thus became known. Furthermore, the exact magnitude of the muscular tension controlled by the activity of each motor fiber has been disclosed by direct observation and by the method of counting motor nerve fibers to a given muscle whose total tension capacity is known. The two methods are in accord and have given this striking information, that a single motor nerve fiber may control as much as 40 to 50 gms of tension.[3] A full account of these investigations is contained in a book by Sherrington and his pupils, published by the Oxford Press a few months ago under the title "Reflex Activity of the Spinal Cord."

In addition to the fundamental disclosures just mentioned, Sherrington has offered a broad conception of the function of the nervous system—the principle "integration," which was first put forward in his Silliman lectures at Yale in 1905. This has now become basic to psychology as well as to neurology and neurophysiology, and it richly justifies the designation applied to Sherrington a year ago, when receiving an honorary degree in Berne, of "the philosopher of the nervous system."

J. F. FULTON

YALE UNIVERSITY

[1] Dreyer and Sherrington, *Proc. Roy. Soc.*, 90B.

[2] Sassa, 1921, Liddell, 1923–1925; Creed, 1928; Cooper and Denny-Brown, 1927; and Eccles, 1929–1930—all in *Proc. Roy. Soc.*

[3] J. C. Eccles and C. S. Sherrington, *Proc. Roy. Soc.*, 106B, June, 1930.

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PROFESSOR EDGAR DOUGLAS ADRIAN

PROFESSOR EDGAR DOUGLAS ADRIAN

EDGAR DOUGLAS ADRIAN, who has been awarded the Nobel Prize in Medicine and Physiology in association with Sir Charles Scott Sherrington, is Foulerton professor of the Royal Society and fellow of Trinity College, Cambridge. The award has been made to him in recognition of his brilliant and fundamental discoveries concerning the mechanism of sense organs and motor nerve cells and the nature of nerve messages. Inasmuch as these messages give rise to sensation and effect the control of muscular contractions, their analysis has been of basic importance to the medical and biological sciences and has laid the foundation for far-reaching advances in neurology.

About seven years ago Professor Adrian succeeded in recording for the first time the impulses in single nerve fibers. In order to determine the context of the messages going from the sense organs to the central nervous system he registered the variations in electrical potential which are associated with nervous activity. Initial experiments showed, however, that because the nerve trunks contain large numbers of fibers which are in independent activity it was difficult to follow and to analyze the response of the individual units. In order to overcome this difficulty, he developed a technique which enabled him to cut away all but one of the sense organs connected with the nerve trunk under investigation. It thus became possible to deal with a nerve in which there were impulses coming from a single sense organ. A further difficulty remained, however, for the electrical pulses in this single unit of the nervous system were too small to operate an electrical recorder sufficiently rapid to follow these brief transients. He therefore employed a vacuum tube amplifier to magnify the nerve potentials many thousand times and then transformed them into a moving beam of light recording on a photographic film or into sound issuing from a loud speaker.

By such means he found that the discharge from a sense organ consists of a series of nerve impulses of a definite frequency, which is greater the greater the intensity of the stimulus. Furthermore, as the strength of stimulus is increased more receptors are brought into action. And so he established the fundamental fact that the neural basis for varying intensities of sensation is a variation in the number of impulses going into the central nervous system, as determined by the frequency of the impulses and the number of active units. A continued constant stimulus produces a train of impulses of a decreasing frequency, thereby explaining the subjective phenomenon of adaptation. The messages from a wide variety of sense organs have been investigated and he has shown their fundamental character to be the same, although certain differences in the form of the impulses may play a part in determining differences in the quality of sensation. His studies of impulses in pain fibers are the foundation for a better understanding of one of the most difficult problems in medical science.

How these impulses act upon the central nervous system and interact to produce coordinated muscular activity has been one of Sherrington's major fields of investigation. By recording the motor impulses resulting from such central activity Adrian has given conclusive answers to questions regarding the regulation of muscular contraction. He has found that there is discharged from the cells in the central nervous system to the muscle fibers supplied by a single nerve fiber a series of impulses of a frequency determined by the degree of central excitation. A weak contraction he has shown to be the result of a low frequency of impulses in comparatively few nerve fibers. A strong contraction, on the other hand, is developed as a result of a high frequency of impulses in many fibers.

Although Adrian has already achieved spectacular success in revealing many of the fundamental properties of nervous action, it is fair to say that these advances are only an indication of what may be expected from his remarkable experimental attack. He has developed a method and point of view which is capable of shedding new light on the regulation of a great diversity of bodily functions. Only recently, for instance, he has analyzed the impulses going to the blood vessels over the sympathetic nerve fibers regulating blood pressure.

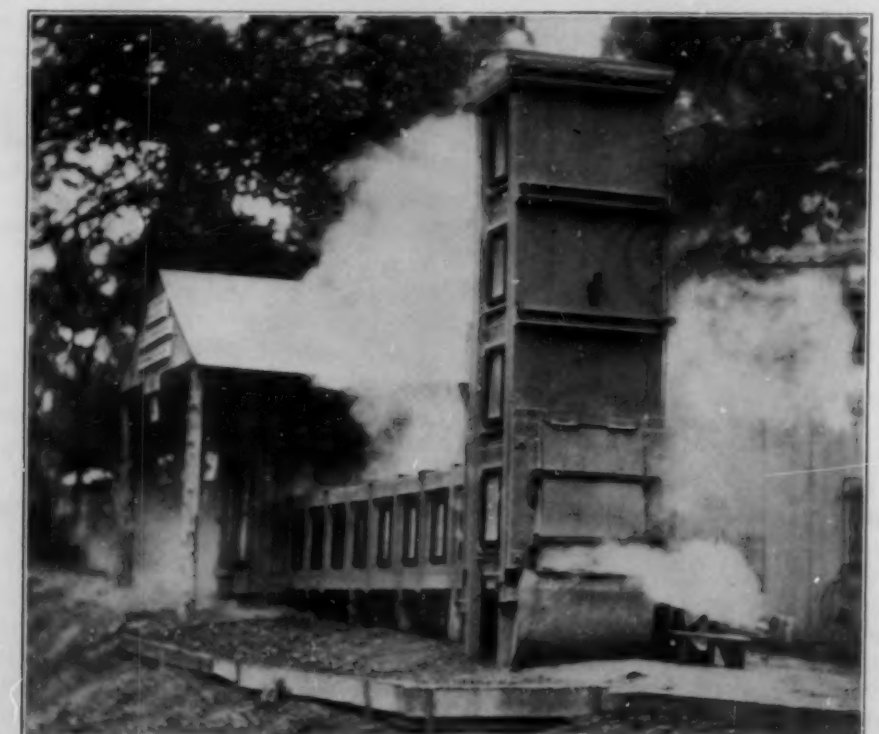
It is particularly appropriate that the Nobel Prize should be awarded jointly to Sherrington and Adrian. Although they have never worked in collaboration, they are warm friends and have long been intimately associated in the affairs of the Physiological Society and the *Journal of Physiology*. Carried out independently and by different methods, their investigations have in a remarkable way fitted together into a clear and dramatic explanation of the manner in which the nervous system controls the activities of the living organism.

DETLEV W. BRONK
UNIVERSITY OF PENNSYLVANIA

OUR HEALTH AND SAFETY

THE autumn weeks have seen meetings of several national and regional associations concerned with human health and safety, from both the personal and the community angle.

The American College of Surgeons



DANGER IN DUST

ARTIFICIAL EXPLOSIONS OF VARIOUS INDUSTRIAL AND FOOD DUSTS, UNDER CONDITIONS SIMULATING THOSE OF COMMERCIAL PLANTS, ARE PRODUCED IN THIS LABORATORY AT THE ARLINGTON FARM OF THE U. S. DEPARTMENT OF AGRICULTURE. THE EXPLOSION HERE SHOWN WAS SET OFF DURING THE RECENT SAFETY CONGRESS IN WASHINGTON.

held its twenty-second clinical congress at St. Louis, from October 17 to 21, under the presidency of Dr. J. Bentley Squier, of New York. Dr. Allen B. Kanavel, of Chicago, retiring president, delivered his address on "Intangibles in Surgery." The John B. Murphy Oration in Surgery was delivered by Sir William I. de Courcy Wheeler, of Dublin, on the subject, "Pillars of Surgery." Dr. Robert Andrews Millikan, director of the Norman Bridge Laboratory of Physics, California Institute of Technology, gave a fellowship address on "Some New Things in Physics." The meeting was marked by a number of notable symposia.

The American Public Health Association held its sixty-first annual meeting in Washington, D. C., from October 24 to 27. Included among its sectional sessions were: vital statistics, industrial hygiene, child hygiene, public health education, public health nursing, food and nutrition, epidemiology and many other topics.

Following shortly after the meeting of the Public Health Association, the National Safety Congress and Exposition was held in Washington, from October 3 to 7. A special feature of the meeting was a demonstration of the laboratory for the study of dust explosions at the Arlington farm of the U. S. Department of Agriculture.

A regional conference on social hygiene, sponsored by the Social Hygiene Society of the District of Columbia, was held in Washington, from October 27 to 29. The fifth annual graduate fortnight of the New York Academy of Medicine was held in New York, from October 17 to 28; it was devoted to the general subject "Tumors."

PROTEAN BEHAVIOR OF BACTERIA

WHETHER or not bacteria change their forms through definite life-cycle stages is becoming more and more a moot point among biologists. Very early in the history of bacteriology it became known that at least some species assume distorted shapes in cultures which have been allowed to become too old and to accumulate too high a concentration of katabolic products. The spore-forming ability of many species was also among the first things learned about bacterial physiology.

These form-changes, however, were ascribed to unfavorable environmental conditions, and spore-formation in particular was considered to be definitely adaptational. The question still remained whether these minutest of living things passed through changes analogous to the astonishing metamorphoses observed in many protozoa, or to the larva-pupa-adult phases of some insects.

Much experimentation was devoted to this question, largely by means of modifying the nutrient media in which bacterial cultures are grown. Important pioneer work was done in this field by Dr. Philip Hadley, of the University of Michigan. Following the lead of the now famous d'Herelle experiments that brought about the discovery of bacteriophage, Dr. Hadley was able to produce filter-passing phases of ordinary bacteria by suitable culturing. Even more sensational was the announcement in the summer of 1931 by Dr. Arthur I. Kendall, of Northwestern University, that with his special "K" medium he could at will reverse filterable and visible phases of many species, produce visible phases from pathogenes hitherto known only as filter-passers, and apparently even regenerate staphylococci out of the bacteriophage that had "destroyed" them.

These discoveries, and others like them, tended to support the theory that all the filtrable viruses are "alive," and even that they may all have visible

phases, awaiting only proper culturing to be demonstrated. But this theory has received a sharp setback from the work of Dr. Carl G. Vinson, formerly of the Boyce Thompson Institute for Plant Research and now at the University of Missouri. Dr. Vinson has succeeded in obtaining the virus of tobacco mosaic in nearly pure crystalline form, with indications that it is a non-living proteinaceous substance, more or less analogous to an enzyme in its make-up and action. Presumably other filterable viruses, at least those of the other mosaics and related plant diseases, resemble the one investigated by Dr. Vinson.

In the meantime, the debate over the reality of life cycles in bacteria continues, with evidence advanced on both sides. Miss Alice C. Evans, senior bacteriologist of the U. S. Public Health Service, has found that the causal organism of encephalitis lethargica, the so-called European sleeping sickness, which is normally a coccus, at times assumes a rod-shaped form, and occasionally becomes a filter-passer as well. This discovery is of immediate diagnostic value as well as of theoretic importance, because hitherto the presence of rod-shaped bacilli in a culture of coccoid forms was naturally taken as a sign of contamination. Now they may signify not a mixed culture but a metamorphosing one.

Dr. Ralph G. Wyckoff, of the Rockefeller Institute for Medical Research, holds that bacterial life cycles have no real existence. He followed the development of bacteria for a total of 600 hours with a specially constructed micro-motion camera, tracing their changes as their nutrient media and other environmental factors were changed. The organisms always tended to resume their normal form when restored to normal conditions, he stated. Likewise, he does not think that the germs have a filterable phase distinct from their normal one. His studies led him to the opinion that the change in food and environmental factors enables the organisms to pass through filters, not by changing their forms but by another process which may, for instance, make them more slippery or more compressible. Dr. Kendall's "K" medium, he pointed out, has been found to aid the passage of normal bacteria through fine filters.

Support for Dr. Wyckoff's point of view can be found in the results obtained at the Mayo Clinic by Dr. Edward C. Rosenow. He was able to detect coccoid and diplococcoid organisms in filtrates of poliomyelitis and herpes encephalitis viruses, by the use of the remarkable microscope invented by Dr. Royal Raymond Rife, of San Diego. He also confirmed the findings of Dr. Kendall, who had seen small, active, oval bodies, turquoise-blue in color, in the filtrable phase of typhoid bacilli.

Another aspect of the Proteus-like behavior of bacilli has been developed by Miss Agnes Quirk, of the U. S. Department of Agriculture. She was concerned primarily with the colony-form rather than with the form of the individual organism. The two bacteria species causing potato black rot and plant tumor form two types of colony, "rough" and "smooth," when cultured on solid media. Though they are microscopically indistinguishable, the species had been provisionally regarded as being divided into separate strains. Miss Quirk has shown that either type of colony can be produced at will by suitable manipulation of the hydrogen ion concentration in the medium. She has extended her work to thirteen plant pathogens; and Major James S. Simmons, of Walter Reed Hospital, has used the same technique with success on a strain of typhoid bacilli. Miss Quirk has also been able to produce filtrable phases of her bacteria.

FRANK THONE

SCIENCE SERVICE

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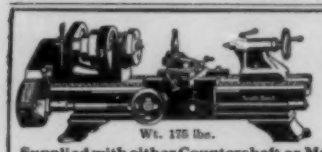
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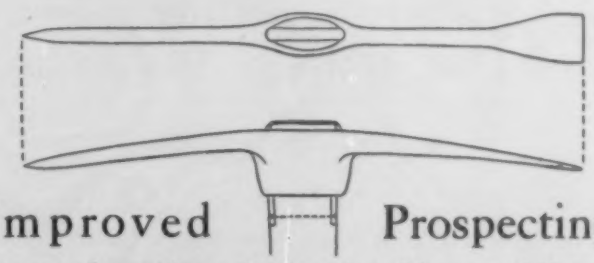

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